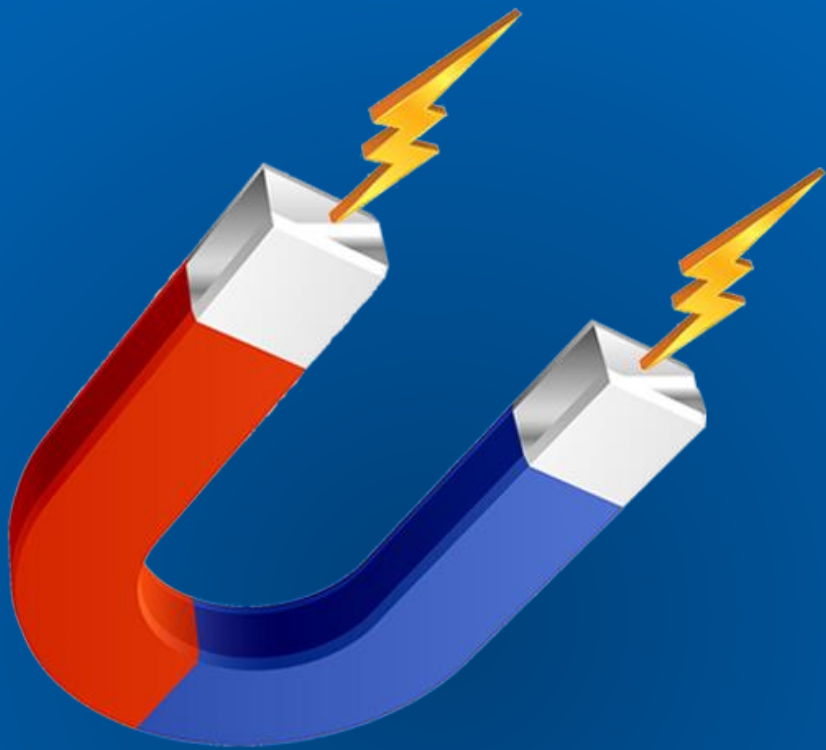
4.MOVING CHARGES AND MAGNETISM



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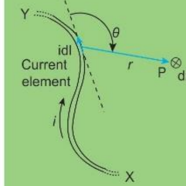
MOVING CHARGES AND MAGNETISM

BIOT – SAVART'S LAW

The Biot – Savart law gives the relationship of magnetic field at any point with current carrying element. $dB = \frac{\mu_o}{4\pi}\int\frac{d\vec{\ell}\times\vec{r}}{|r|^3}$

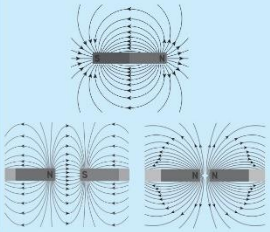


In vector form : $\vec{B} = \frac{\mu_0 i}{4\pi}\int\frac{d\vec{l}\times\vec{r}}{|r|^3}$

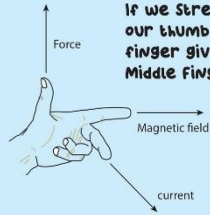
MAGNETIC FIELD

The region around a magnet in which its magnetic influence can be experienced is called magnetic field. ($\vec{B}$)

- S.I unit Tesla (T).
- Denote coming out.
- Denote going into the paper.

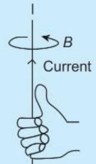


FLEMING'S LEFT-HAND RULE



If we stretch our finger's like image, then our thumb gives direction force. Index finger gives direction of magnetic field & middle finger gives current.

RIGHT-HAND RULE

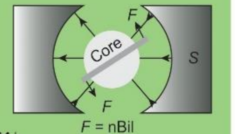


Holding a currant carrying conductor in right hand in such a way that thumb points in the direction of current and curling finger's gives direction of magnetic field.

MOVING COIL GALVANOMETER

It works on the principle that a current carrying coil in uniform magnetic field, experience a torque.

- Torque – $\tau = nBiA$
  n = Number of coils
  A = Area
- Restoring Torque $= \tau = K\phi$
  ϕ = Deflection
- In equillibrium $= \tau = nBiA = K\phi$
  $\rightarrow i = \frac{K}{nBA}\phi$



Current sensitivity : $S_i = \frac{\phi}{i} = \frac{nBA}{K}$

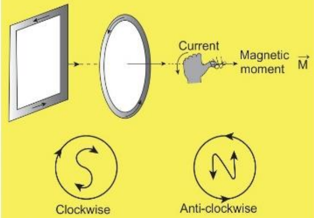
Voltage sensitivity : $S_v = \frac{\phi}{i} = \frac{Si}{R} = \frac{nBA}{KR}$

CURRENT CARRYING LOOP AS MAGNETIC DIPOLE

The current carrying coil behaves as a bar magnet and magnetic moment of such coil can be expressed as $M = niA$.

n = Number of coils

A = Area

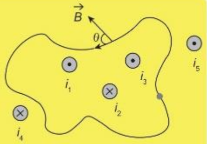


Direction of current in coil show's polarity

AMPERE'S CIRCUITAL LAW

This law states that the line integral of magnetic field $\vec{B}$ around a closed loop is equal to μ_0 times the net current enclosed by the loop.

$\oint\vec{B}.\vec{dl} = \mu_o\sum i_{enclosed}$



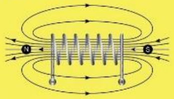
MAGNETIC FIELD OF TOROID :

$B = \mu_0 ni$: Here, $n = \frac{N}{2\pi r}$

r = average radius

N = Total number of turns in toroid.

MAGNETIC FIELD OF LONG SOLENOID :

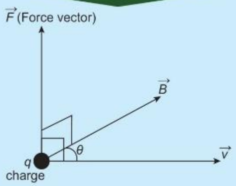


$B = \mu_0 ni$

N = Number of turn's per unit length.

i = Current flowing

MAGNETIC FORCE ON A MOVING CHARGED PARTICLE



$\vec{F} = q(\vec{V}\times\vec{B})$, $|\vec{F}| = qVB\sin\theta$

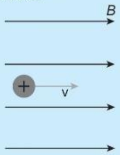
θ = Angle between direction of motion of charge and magnetic field.

- Power delivered by magnetic force to charged particle is always zero.

$P = \vec{F}.\vec{V} = \upsilon\,[\because(\vec{F}\perp\vec{V})$

Path of charged particle in external magnetic field:-

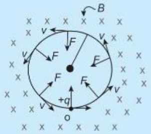
Case 1:



When charged particle is moving parallel or antiparallel to magnetic field: Magnetic force F = qvB Sinθ = 0

Charge particle move un – deviated radius of path is r = ∞

Case 2:



When charge particle moving perpendicular to magnetic field:- Magnetic force – F = qvB Sin90° = qvB

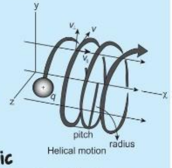
$\therefore\frac{mv^2}{r} = qvB \Rightarrow r = \frac{mV}{qB}$

∴ Radius of circular- path $r = \frac{mV}{qB}$

Time period – $T = \frac{2\pi m}{qB}$

Case 3:

When charge particle is moving in any orbitary direction with respect to magnetic field:- Magnetic force $F = q(\vec{V}\times\vec{B}) = qvB\sin\theta$



Charge particle follow helical path.

Radius of helix – $r = \frac{mV\sin\theta}{qB} = \frac{mV_\perp}{qB}$

Time period – $T = \frac{2\pi r}{qB}$

Bohr Magneton

The magnetic moment associated with an electron which is revolving in first orbit of an atom.

It is represented as:-

$\mu_B = \frac{eh}{4\pi m} = 0.923\times10^{-23}\ Am^2$

e = electronic charge

m = mass of electron

h = Planck & constant

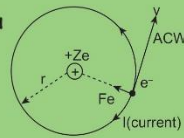
ATOMIC MAGNETISM

When an electron revolves, due to its movement it behaves as a current carrying loop and produce magnetic field. This is known as atomic magnetism.

Orbital Current

The orbital current generated by electron revolving around nucleus $-I = \frac{e\omega}{2\pi}$

ω is angular velocity of electron.



Magnetic induction at nucleus position

$B = \frac{\mu_o I}{2r} = \frac{\mu_o ew}{4\pi r}$

r = orbital radius, I = orbital current

Magnetic moment circular orbit

$M = IA = \frac{ewr^2}{2} = \frac{evr}{2}$ A= Area of orbit.

Relation between Magnetic Moment and Angular Momentum of Charge Particle

$M = \frac{qL}{2m} \Rightarrow \frac{M}{L} = \frac{q}{2m}$

Where, M = Magnetic moment
L = mvr – Angular momentum
m = mass of particle.

Torque Acting on Current Carrying Coil:	Work done in Rotating a coil Placed in Magnetic Field:	Potential Energy of a Coil Placed in Magnetic Field:
$\tau = nBiA\sin\theta$ N = Number of turns A= Area I = current Magnetic moment – $\vec{M} = i\vec{A}$ $\therefore\vec{\tau} = \vec{M}\times\vec{B}$	$W = MB\,(1-\cos\theta)$ Here, M = Magnetic Moment of coil.	$U = -MB\cos\theta$ $= -\vec{M}.\vec{B}$

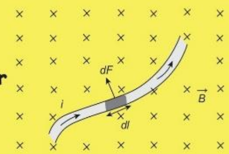
MAGNETIC EFFECT OF CURRENT

Force on current carrying conductor in magnetic field

In uniform magnetic field the total force acting on conductor of length L is expressed as.

$\vec{F} = i(\vec{L}\times\vec{B}) = iLB\sin\theta$

θ = Angle made by current direction with magnetic field.

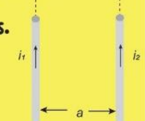


Force between two parallel current carrying conductor' s

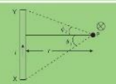
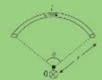
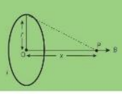
$F_1 = F_2 = F = \frac{\mu_o i_1 i_2}{2\pi a}\times L$

a = distance between two wires.

L = Length of wires.



MAGNETIC FIELD OF SOME SPECIAL CURRENT CARRYING CONDUCTORS

Shape of current carrying conductor	Formula	Special case
	$\vec{B} = \frac{\mu_o i}{4\pi r}(\sin\phi_1 + \sin\phi_2)\hat{\eta}$	For infinitely long conductor.
	$\vec{B} = \frac{\mu_o i}{2\pi r}(\frac{\theta}{360_o})\hat{\eta}$	For semicircular arc.
	$\vec{B} = \frac{\mu_o i}{2\pi r}\hat{\eta}$	r = radius of coil.
	$\vec{B} = \frac{\mu_o ir^2}{2(x^2+r^2)^{3/2}}$	X = distance from the center of coil.

MOVING CHARGES AND MAGNETISM

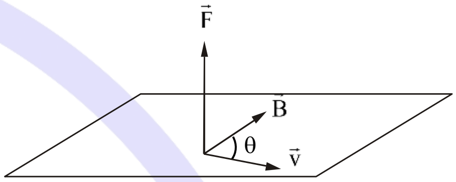
Introduction

A gravitational field is associated with a mass. An electrostatic field is associated with a charge. A magnetic field is in a region surrounding a current carrying conductor.

- An electric charge $\xrightarrow{\text{causes}}$ an electric field $\xrightarrow{\text{affects}}$ an electric charge
- A moving electric charge (electric current) $\xrightarrow{\text{causes}}$ a magnetic field $\xrightarrow{\text{affects}}$ a moving electric charge

Magnetic force on a charged particle moving in a magnetic field

The force exerted by a magnetic field on a moving electric charge or a current carrying conductor is called magnetic force.



Force on a moving charge

A charge q moving with a velocity $\vec{v}$, in a magnetic field $\vec{B}$, experiences a force $\vec{F}$. It is given by

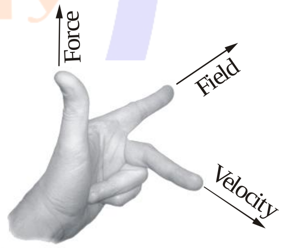
$$\vec{\mathbf{F}} = \mathbf{q}\,\vec{\mathbf{v}}\times\vec{\mathbf{B}}.$$

- The magnitude of the magnetic force is F = q vB sin θ, where θ is the angle between $\vec{v}$ and $\vec{B}$.
- The direction of $\vec{F}$ is that of $\vec{v}\times\vec{B}$.
- F is zero, when $\vec{v}$ is parallel or anti parallel to $\vec{B}$ (θ = 0 or 180°).
- F is maximum when a charged particle moves in a direction perpendicular to the direction of $\vec{B}$ (θ = 90°). F_{max} = q VB sin 90° = q vB.
- The work by the magnetic force on a charged particle is zero since $\vec{F}$ is perpendicular to $\vec{v}$. Thus, a magnetic field cannot change the speed and kinetic energy of a charged particle.

Fleming's left hand rule

The direction of the force on a charged particle moving perpendicular to a magnetic field is given by Fleming's left hand rule.

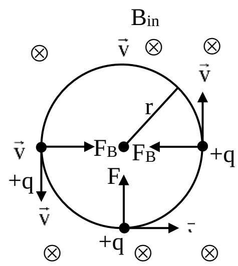
Stretch the first three fingers of the left hand such that they are mutually perpendicular. If the forefinger is in the direction of the field, the middle finger in the direction of velocity of the positively charged particle then the thumb gives the direction of the mechanical force.



Fleming's left hand rule

Motion of a charged particle with $\vec{v}$ perpendicular to $\vec{B}$

Consider a positively charged particle moving in a uniform magnetic field. When the initial velocity of the particle is perpendicular to the field, (in the figure, the magnetic field is perpendicular to the plane of the paper and inwards) the particle moves in a circular path whose plane is perpendicular to the magnetic field.



Thus, the centripetal force $\frac{mv^2}{r}$ is provided by the magnetic force qvB,

where r = radius of the circular path.

$$\therefore\ \mathbf{r} = \frac{\mathbf{mv}}{\mathbf{qB}}.$$

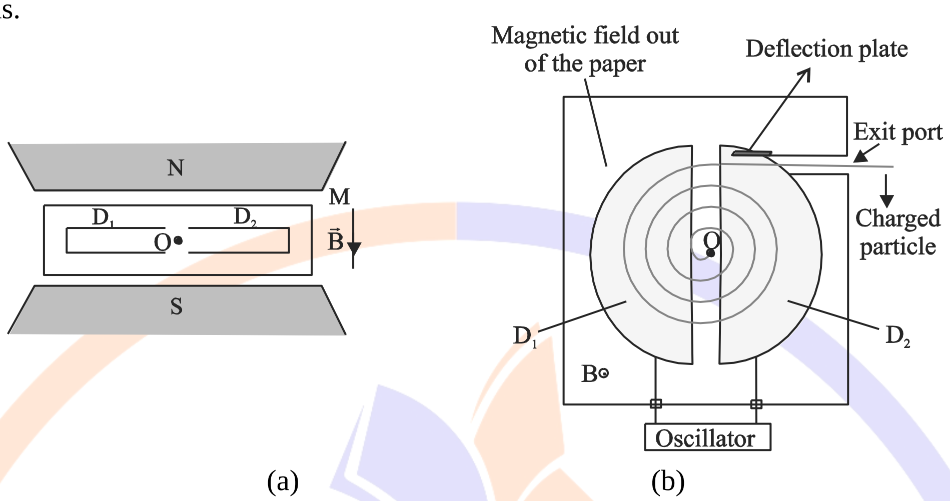
The **angular speed** of the particle, $\boldsymbol{\omega} = \frac{\mathbf{v}}{\mathbf{r}} = \frac{\mathbf{qB}}{\mathbf{m}}$.

The **period** of circular motion, $\mathbf{T} = \frac{\mathbf{2\pi r}}{\mathbf{v}} = \frac{\mathbf{2\pi}}{\boldsymbol{\omega}} = \frac{\mathbf{2\pi m}}{\mathbf{qB}}$ and frequency $f = \frac{qB}{2\pi m}$

Thus, the angular speed of the particle, period of the circular motion and frequencies of rotation do *not* depend on the translational speed of the particle or the radius of the orbit, for a given charged particle in a given uniform magnetic field. This principle is used in the design of a particle accelerator called cyclotron.

Cyclotron

Cyclotron is a device used to accelerate charged particles to very large kinetic energies by applying electric and magnetic fields.



Schematic diagram of cyclotron

- ### Expression for kinetic energy

  The maximum kinetic energy, of the ion as it emerges from the cyclotron will then be

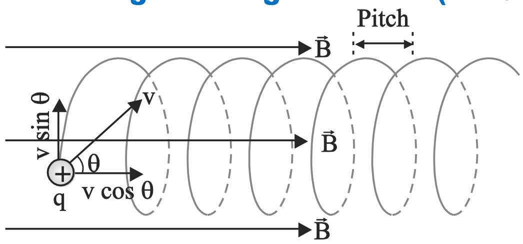
  $(\text{Kinetic energy})_{max}, K_{max} = \dfrac{B^2q^2R^2}{2m} \Rightarrow K_{max} \propto \dfrac{q^2}{m}.$

- ### Cyclotron frequency

  The frequency f, of the oscillator required to keep the ion in phase is the reciprocal of the time in which the particle makes one revolution. This is called the cyclotron frequency given by $f = \dfrac{Bq}{2\pi m}$

  It can be shown that kinetic energy = $2m\pi^2 f^2R^2$

Helical path of a charged particle moving in a magnetic field (0 < θ <90°)



- If a charged particle moves in a uniform magnetic field with its velocity at some arbitrary angle θ ($0 < \theta < 90°$) with respect to a magnetic field $\vec{B}$, the path is a helix.
- The axis of the helix is along the direction of B.
- The perpendicular component of velocity ($v \sin\theta$) determines the radius (r) of the helix.

  Then, $r = \dfrac{mv\sin\theta}{qB}$

- The pitch of the helix $p = (v\cos\theta)T$, where T is the period of the circular motion and is given by $T = \dfrac{2\pi m}{qB}$

  The Pitch of the helical path (p) is the distance travelled by the particle along the direction of the field in one period of revolution of the circular motion.

  $\therefore \; p = \dfrac{2\pi m v\cos\theta}{qB}$

Motion of a charge in combined electric and magnetic fields

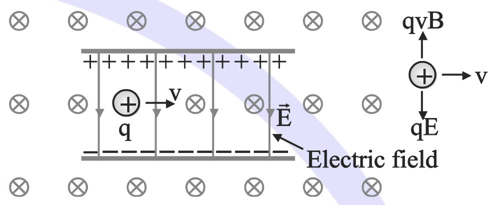
Lorentz force

A charge q moving with a velocity $\vec{v}$ in the presence of an electric field $\vec{E}$ and a magnetic field $\vec{B}$, experiences a force given by $\vec{F} = q\vec{E} + q(\vec{v} \times \vec{B})]$. This force is called the Lorentz force.

This expression for force was deduced by H.A. Lorentz and is based on experimental observations.

Velocity selector

Consider a positively charged particle q, moving with a velocity $\vec{v}$ subjected to uniform electric field $\vec{E}$ and magnetic field $\vec{B}$ acting at right angles to each other, as shown in the figure.



$F_{mag} = qvB$ acting upwards … (1)

$F_{elc} = qE,$ … (2)

Let us make $F_{elc} = F_{mag}$

$qE = qvB$

$$v = \frac{E}{B} \quad \ldots (3)$$

For a given magnitude E and B, v is fixed.

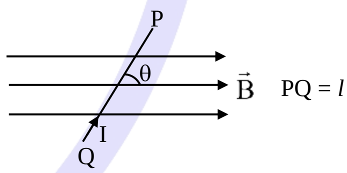
Thus, a particle whose velocity v = E/B alone travels undeflected. Particles whose velocities differ from this value get deflected. Hence, if we inject a stream of particles (each of same charge) with varying velocities into a region of combined fields, we get a fine pencil of particles with a single value of v. In other words this arrangement works as a velocity selector.

Magnetic force on a current carrying wire

The phenomenon in which a current carrying conductor experiences a force in a magnetic field is called the mechanical effect of electric current. This force on the conductor is a manifestation of the force acting on the free electrons in the conductor placed in a magnetic field.

A current carrying conductor placed in a magnetic field experiences a mechanical force. The magnitude of this force given by $F = B\,I\,l \sin\theta$

where B is the magnetic field, I is the current, l is the length of the conductor and θ is the angle between the direction of the current and the magnetic field.



- Vector form : $\vec{F} = I\vec{l} \times \vec{B}$
- The force is maximum when $\theta = 90°$

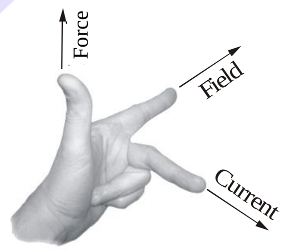
i.e., when a current carrying conductor is placed at right angles to the direction of the magnetic field, $F_{max} = B\,I\,l$

- The force exerted is zero when $\theta = 0$, or 180° i.e., when a current carrying conductor is placed parallel to the direction of the magnetic field or antiparallel

The direction of the force is given by **Fleming's left hand rule.**

The rule is stated as follows.

Stretch the fore finger, the middle finger and the thumb of the left hand such that they are mutually at right angles. If the fore finger shows the direction of the magnetic field and the middle finger the direction of the current, the thumb shows the direction of the mechanical force on the conductor.



Fleming's left hand rule

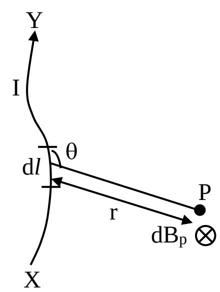
Biot Savart's Law or Laplace's Rule

It states that the magnetic field (dB) at a point P at a distance r from a conductor of length dl carrying a current I is,

(i) directly proportional to I .

(ii) directly proportional to dl

(iii) directly proportional to the sine of the angle between the current element and the line joining the mid point of the conductor to the given point.



(iv) inversely proportional to r^2.

i.e., $dB \propto \frac{I\,dl\sin\theta}{r^2}$

$\therefore\ dB = \frac{\mu_0}{4\pi}\frac{I\,dl\sin\theta}{r^2}$.

The direction of dB is perpendicular to the plane containing both the conductor and the given point.

The direction of the magnetic field around a current carrying conductor can be obtained by any one of the following rules.

1. **Maxwell's right handed corkscrew rule**

If we imagine a right handed corkscrew to be rotated such that its tip advances in the direction of the current, then the direction of rotation of the screw head gives the direction of magnetic field lines.

2. **Right hand clasp rule**

If we imagine a current carrying conductor to be clasped with the right hand such that the thumb indicates the direction of electric current, then the direction in which the fingers encircle the conductor gives the direction of the magnetic field lines.

Magnetic Field Lines

Magnetic field can be better understood by visualising it using the concept of magnetic field lines.

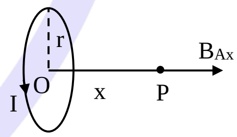
Magnetic field lines are imaginary lines with the following characteristics:

1. They are continuous, closed loops.
2. The tangent to a magnetic field line at a point gives the direction of the magnetic field at that point.
3. Two magnetic field lines never intersect.
4. The number of field lines normal to a given surface is called magnetic flux. Magnetic flux is measured in weber (Wb).

The magnetic flux per unit area is the strength of the magnetic field or simply the magnetic field. It is also called magnetic flux density (B). It is measured in Wb m^{-2} = T (tesla).

Magnetic field at a point on the axis of a circular coil carrying current

Consider a coil of n turns and radius r carrying a current I. The magnetic field (B) at a point P on the axis at a distance x from the centre is given by $B = \frac{\mu_0}{4\pi}\frac{2\pi n I r^2}{(x^2+r^2)^{3/2}}$.



The direction of B is along the axis. When the current is counterclockwise, the field along the axis is towards the observer facing the coil.

Magnetic field at the centre of a circular coil carrying current

If the current through the coil of n turn of radius r is I, then, the field at the centre of the coil is $B = \frac{\mu_0}{4\pi}\left[\frac{2\pi n I}{r}\right] = \frac{\mu_0 nI}{2r}$

The field $\vec{B}$ at the centre is perpendicular to the plane of the coil.

If the coil is in the plane of the paper and the current is

(a) clockwise, then $\vec{B}$ is into the plane of the paper.

(b) anti-clockwise, then $\vec{B}$ is out of the plane of the paper.

Ampere's circuital law

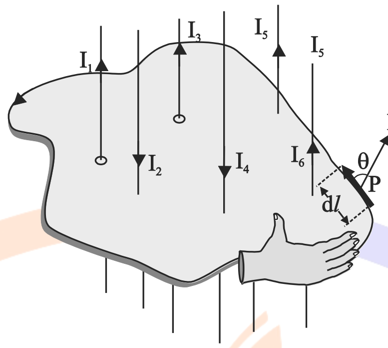
Ampere's circuital law for calculation of magnetic field due to distributed currents is analogous to Gauss' law in electrostatics used to calculate electric field due to distributed charges.

Statement

The line integral of magnetic field along a closed curve enclosing an arbitrary surface is equal to μ_0 times the total current passing through the surface.

Explanation

Figure shows the number of currents I_1 I_2 I_3 ..... producing a magnetic field $\vec{B}$.



$$\oint \vec{B}.\,\vec{dl} = \mu_0 I_{enclosed},$$

where $I_{enclosed} = \Sigma I_j$, $(\Sigma I_j = I_1 - I_2 + I_3 - I_4 + I_5 + I_6)$

and μ_0 = permeability of free space.

$\vec{B}$ is the magnetic field at a point P on the boundary of the surface making an angle θ with the length element $\vec{dl}$ on the boundary. $\oint \vec{B}.\vec{dl}$ is the sum of all the $\vec{B}.\vec{dl}$ products over the complete boundary or path. This closed boundary is called the *amperean loop.*

Procedure to apply Ampere's law

Step 1:

If I_1, I_2, I_3.... etc., are the currents causing a magnetic field at a point P, mark a surface through which all these currents pass and indicate the boundary of the surface with P on it.

Step 2:

Mark $\vec{B}$ in any arbitrary direction.

Step 3:

Mark a length element $\vec{dl}$ at P and let the angle between $\vec{B}$ and $\vec{dl}$ be marked θ.

Step 4:

Let the sense of carrying out the integration be marked arbitrarily. In the given case, it is marked anticlockwise.

Step 5:

Keep your right hand with the fingers half curled so that the fingers held along the boundary (amperean loop) indicate the direction of integration. Mark all currents indicated by the direction of the thumb as +ve and those opposite the thumb as –ve.

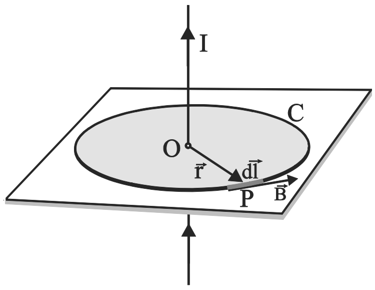
Step 6:

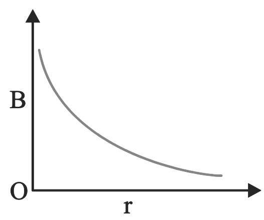
Evaluate B. If B works out to be +ve, the marked direction of $\vec{B}$ is correct. Otherwise, reverse the direction of $\vec{B}$.

Magnetic field at a point due to a long straight conductor carrying a current

Consider an infinitely long conducting wire, carrying a current I. Let P be a point close to it at a distance r from it. (r is much less than the length of the conductor).

$$B = \frac{\mu_0 I}{2\pi r}$$





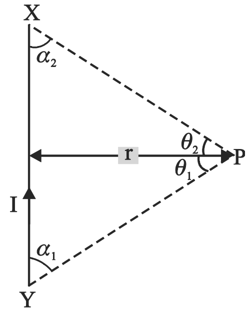
The variation of magnetic field B with distance r from the conductor is shown in the figure.

The direction of $\vec{B}$ is given by the right hand clasp rule.

For a short conductor the magnetic field at a point P near it can be shown to be given by,

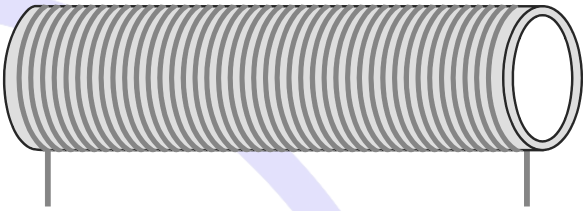
$$B_P = \frac{\mu_0}{4\pi}\frac{I}{r}(\sin\theta_1 + \sin\theta_2) \qquad \text{or}$$

$$B_P = \frac{\mu_0}{4\pi}\frac{I}{r}(\cos\alpha_1 + \cos\alpha_2)$$



Magnetic field due to a solenoid

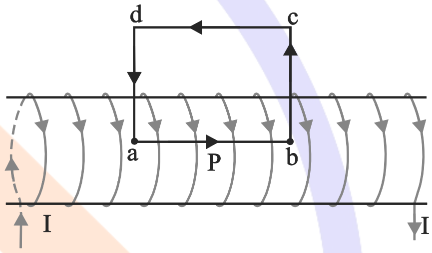
A nearly uniform magnetic field can be produced using solenoids. A solenoid is a helical winding of a conducting wire with neighbouring turns closely spaced (Fig). wound on a cylinder such that the plane of each turn is parallel to the next and perpendicular to the axis of the cylinder.



Expression for magnetic field produced by a long solenoid

From Ampere's circuital law, $\oint \vec{B}\cdot\vec{dl} = \mu_0 i$ i.e., $Bl = \mu_0 I n l$

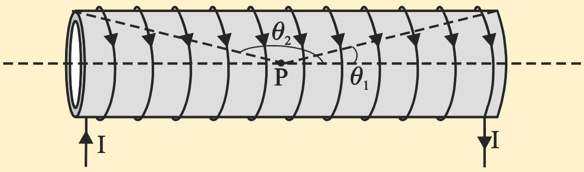
or B = $\mu_0 nI$



Direction of the field is along ab. We see that the magnetic field does not depend on the position of point P inside the solenoid. Hence the magnetic field inside a long solenoid (except at the ends) is uniform in magnitude and direction.

- For a small solenoid of length L compared to its radius R, (Fig) the magnetic field at the centre is

$$B = \frac{\mu_0 nI}{2}(\cos\theta_1 - \cos\theta_2)\,.$$



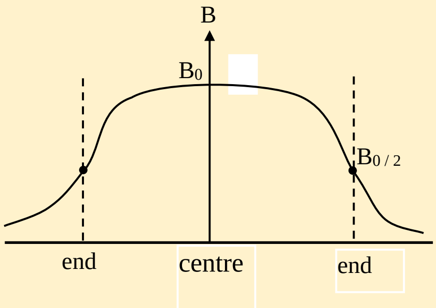
- For a long solenoid (L >> R)

$\theta_{1\le} \approx 0°$ and $\theta_2 \approx 180°$

$$B = \frac{\mu_0 nI}{2}[1-(-1)] = \mu_0 nI$$

- Magnetic field at one end of a long solenoid ($\theta_1 = 0$, $\theta_2 = 90°$) is

$$B = \frac{\mu_0 nI}{2}(1-0) = \frac{\mu_0 nI}{2}$$



- The magnetic field inside a solenoid can be greatly increased by introducing a ferromagnetic material like iron, which has a large relative permeability μ_r. Then the magnetic field in the solenoid will be $B = \mu_0\mu_r nI$.

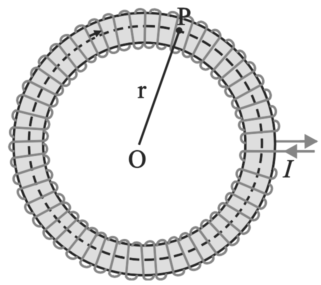
▪ A current carrying solenoid when suspended freely comes to rest just like a suspended bar magnet along the north and south direction.

When looking at one end of a solenoid, (i) if the current is anticlockwise as shown in figure (1), the end face of the solenoid behaves like a north pole of a bar magnet (ii) if current is clockwise as in figure (2), the end face behaves like south pole of a bar magnet

Figure 1: anti-clockwise current

Figure 2: clockwise current

Magnetic field due to a toroid



A toroid is a hollow ring on which a large number of closely spaced turns of a conducting wire are wound. It may be treated as a long solenoid bent into the shape of a doughnut. If a current I is passed through it, the magnetic field lines inside the toroid will be concentric circles.

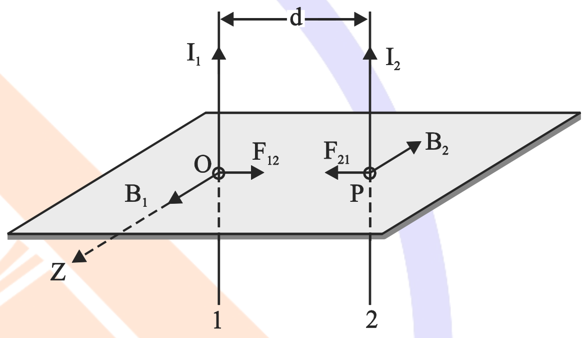
Let B be the field at a point P at distance *r* from the centre of the toroid O.

From Ampere's theorem, $2\pi rB = \mu_0 \times NI \quad \therefore \; B = \dfrac{\mu_0 NI}{2\pi r}$

If $n = \dfrac{N}{2\pi r}$ is the number turns per unit length we once again have $B = \mu_0 nI$.

Force between two parallel current carrying conductors

If I_2 is the current in the second conductor, parallel to I_1. Then the a segment of the second conductor of length L experiences a force given by $\vec{F}_{21} = I_2\vec{L} \times \vec{B}$.



This force is directed towards the first conductor and has a magnitude

$$F_{21} = I_2 L \cdot \frac{\mu_0 I_1}{2\pi d} \quad (\because \vec{L} \text{ is perpendicular to } \vec{B})$$

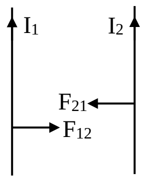
or

$$F_{21} = \frac{\mu_0 I_1 I_2 L}{2\pi d}$$

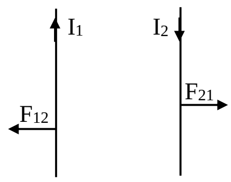
The force per unit length of the second conductor towards the first conductor is $F_{21} = \dfrac{\mu_0 I_1 I_2}{2\pi d}$

Since the first conductor also experiences a force in the field produced by the second conductor, the force per unit length of current I_1 should also be equal to $\dfrac{\mu_0 I_2 I_1}{2\pi d}$ and directed towards I_2.

Thus, **the force per unit length of the conductor** $= \dfrac{\mu_0 I_1 I_2}{2\pi d}$



- If two straight, parallel conductors carry current in the same direction, they attract each other, with the same force.
- If two straight, parallel conductors carry current in the opposite direction, they repel each other, with the same force.



Current loop as a magnetic dipole

At large distances as the axis of the current loop, we have

$$B = \frac{\mu_0 IA}{2\pi x^3} = \frac{\mu_0}{4\pi}\frac{2IA}{x^3}$$

πR^2 = Area A of the loop

This equation is analogous with the equation for the electric field on the axis of an electric dipole,

$$\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{2\vec{p}}{x^3}$$

Hence, the term IA is the magnetic analogue of the electric dipole moment p hence IA is called the magnetic moment,

$$\vec{m} = I\vec{A}$$

$$\vec{B} = \left(\frac{\mu_0}{4\pi}\right)\frac{2\vec{m}}{x^3} \qquad \text{for } x >>> R$$

The magnetic field produced by a current loop is identical with the electric field produced by an electric dipole. Hence a current loop is equivalent to a magnetic dipole.

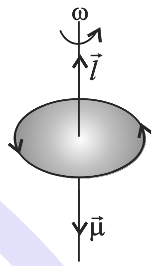
We observe that the magnetic moment depends only on the area of the loop but not on its shape.

Magnetic dipole moment of a revolving electron

Consider an electron revolving in a circular path, typically like an electron revolving around a nucleus. Let the magnitude of the charge on the electron be e and T be its period of revolution.

The current equivalent of the revolving electron is

$$I = \frac{e}{T} \quad \dots (1)$$



If v is the velocity of the electron,

$$v = \frac{2\pi r}{T} \quad \dots (2)$$

From Eqs., (1) and (2)

$$I = \frac{e}{\left(\frac{2\pi r}{v}\right)} = \frac{ev}{2\pi r} \quad \dots (3)$$

The magnetic moment produced by the revolving electron is given by $\mu_l = IA$

$$= \left(\frac{ev}{2\pi r}\right)\pi r^2 = \frac{evr}{2} \quad \dots (4)$$

The direction of this magnetic moment is into the plane of the paper, as if it is due to a clockwise current I.

Expression for gyromagnetic ratio

Magnetic moment of an electron given by $\mu_l = \frac{evr}{2} = \frac{eL}{2m_e}$

In vector form $\vec{\mu}_l = -\frac{e}{2m_e}\vec{L}$

The negative sign indicates that the angular momentum of the revolving electron is opposite to its magnetic moment.

$$\frac{\mu_l}{L} = -\frac{e}{2m_e}$$

Considering only the magnitude of the ratio

$$\left|\frac{\mu_l}{L}\right| = \frac{e}{2m_e}$$

This ratio is called **gyromagnetic ratio** of the electron. Its value is 8.8×10^{10} C kg^{-1}.

This has been verified experimentally.

Bohr magneton

We know that, $\mu_l = \frac{eL}{2m_e} \quad \dots (1)$

Let us consider the Bohr's postulates for quantization of orbits, namely,

$$L = mvr = \frac{nh}{2\pi}, \text{ where } n = 1, 2, 3, \dots \quad \dots (2)$$

$$\mu_l = \frac{e}{4\pi m_e} \times nh$$

The minimum value of magnetic moment is obtained when n = 1

$$(\mu_l)_{min} = \frac{eh}{4\pi me}$$

This minimum value of μ_l is called **Bohr magneton**.

The value of Bohr magneton is $= \frac{1.6\times10^{-27}\times6.63\times10^{-34}}{4\times3.14\times9.1\times10^{-31}\times1.6\times10^{-19}}$ = 9.27×10^{-24} Am^2

Torque on a magnetic dipole (Current loop)

A current loop of area A carrying current I has a magnetic moment, $\vec{M} = I\vec{A}$

The direction of this magnetic moment vector is perpendicular to the plane of the current loop, given by right hand corkscrew rule.

A current loop suspended in a magnetic field is analogous to an electric dipole in an electric field. Hence, it experiences a torque, $\vec{\tau} = \vec{M} \times \vec{B} \quad \therefore \quad \vec{\tau} = I\vec{A} \times \vec{B}$.

The magnitude of the torque is $\tau = IAB\sin\theta$ where θ is the angle between the direction of magnetic field and the magnetic moment. The direction of $\vec{\tau}$ is perpendicular to the plane containing $\vec{M}$ and $\vec{B}$. The tendency of the torque is to align the magnetic moment along the field. The coil tends to rotate until its plane is perpendicular to the magnetic field.

If the coil has n turns, $\tau = n\,A\,I\,B\sin\theta$. When $\theta = 90°$, $\tau_{max} = nAIB$.

Moving coil galvanometer (pointer galvanometer)

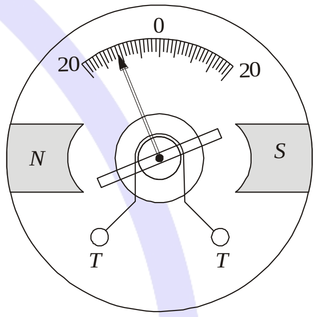


Table galvanometer

It is a device used for accurate measurement of very small currents of the order of microampere. It works on the principle that a current carrying coil when suspended in a magnetic field experiences a torque and then deflects

For small deflection of the coil, the deflection is proportional to the current.

$$I = \left(\frac{C}{nBA}\right)\theta = K\theta\text{, hence } I \propto \theta$$

where, C = couple per unit twist of the suspension wire, n = number of turns in the coil, A = area of the coil, B = magnetic field, θ = deflection of the coil in radian.

Current sensitivity

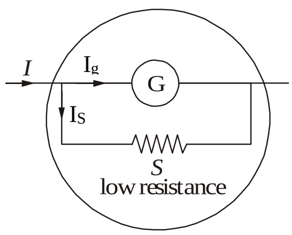
Current sensitivity $\left(\frac{\theta}{I}\right)$ of a galvanometer is numerically equal to the deflection produced in the galvanometer when unit current flows through it.

From the equation $I = K\theta$, we get $\frac{\theta}{I} = \frac{I}{K} = \frac{nBA}{C}$. The galvanometer is sensitive, if it can produce a large deflection for a small current.

The sensitivity can be increased by

1. increasing the number of turns (n) in the coil
2. increasing the magnetic field (B)
3. increasing the area of the coil (A)
4. by decreasing the couple/unit twist of the suspension wire (C). This can be achieved by using a thin and long suspension wire.

Conversion of a pointer galvanometer into an ammeter



Conversion of galvanometer into ammeter

A galvanometer can be converted into an ammeter by connecting a low resistance, called shunt, in parallel to the galvanometer coil.

- Full scale deflection current, $I_g = \frac{IS}{G+S}$, where I is the maximum current (range) to be measured, G is the resistance of the galvanometer and S is the shunt resistance $\therefore\ I_g \propto I$
- $S = \frac{I_g G}{(I - I_g)}$

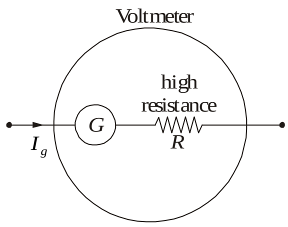
Conversion of a pointer galvanometer into a voltmeter

A galvanometer can be converted into a voltmeter by connecting a high resistance in series with the galvanometer coil.

- P.D, $V = I_g (G + R)$

where V is the range of voltmeter, I_g is the full scale deflection current through the galvanometer, G is the resistance of the galvanometer and R is the high resistance in series $\therefore I_g \propto V$

- $R = \frac{V}{I_g} - G$



Conversion of a galvanometer into an voltmeter

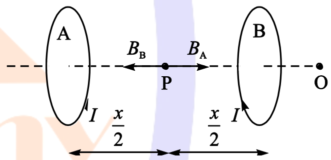
Illustrations

1. Two identical coils A and B are kept coaxially with a separation equal to their diameter. Coil A carries a current *I* in anticlockwise direction and B carries same current *I* but in clockwise direction. The magnetic field at the midpoint on the axis between the two coils is

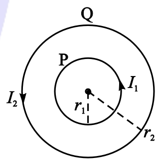
(A) zero (B) $\frac{2\mu_0 n I r^2}{\left[r^2 + \left(\frac{x}{2}\right)^2\right]^{\frac{3}{2}}}$ (C) $\frac{4\mu_0 n I r^2}{\left[r^2 + \left(\frac{x}{2}\right)\right]^{\frac{1}{2}}}$ (D) $4\frac{\mu_0 n I}{r}$

Ans (A)

With respect to the observer at O, the magnetic field at the axial point P due to the coil A is directed towards O whereas that due to B is directed away from O as shown in figure. Since P is the mid point of A and B, the magnetic fields are equal and opposite. Therefore the net magnetic field at the point P is zero.



2. In the figure P and Q are two concentric circular coils having equal number of turns but of radii r_1 and r_2 carrying currents I_1 and I_2 respectively. If the magnetic field at the common centre O is zero, then



(A) $\frac{I_1}{I_2} = \frac{r_2}{r_1}$ (B) $\frac{I_1}{r_1} = \frac{I_2}{r_2}$ (C) $I_1 r_1^2 = I_2 r_2^2$ (D) $I_1 r_2^2 = I_2 r_1^2$

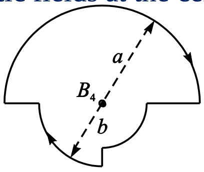
Ans (B)

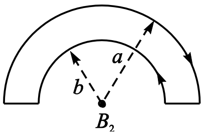
The magnetic fields due to the current loops P and Q are in opposite directions.

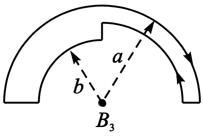
Since the resultant magnetic field is zero at the common centre,

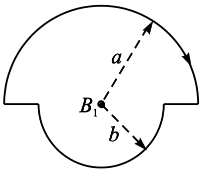
$$B_p = B_Q \Rightarrow \frac{\mu_0 n I_1}{2r_1} = \frac{\mu_0 n I_2}{2r_2} \quad \therefore \frac{I_1}{r_1} = \frac{I_2}{r_2}$$

3. In the loops shown, all curved sections are either semicircles or quarter circles. All the loops carry the same current. The magnetic fields at the centers have magnitudes B_1, B_2, B_3 and B_4. Then,

(i) 

(ii) 

(iii) 

(iv) 

(A) B_4 is maximum (B) B_3 is minimum

(C) $B_4 > B_1 > B_2 > B_3$

(D) B_2 cannot be found unless the dimensions of the section B are known.

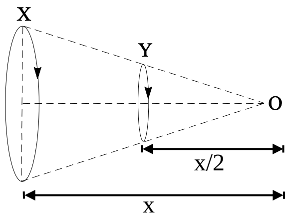
Ans (C)

For B_1 and B_4, the contributions due to the different sections add up. For B_2 and B_3, the contributions due to the outer sections oppose the contributions due to the inner sections. Thus, B_1 and B_4 are greater than B_2 and B_3.

For B_4, there is a section with radius < b and hence it contributes more than the semicircular section of radius b does for B_1. Thus $B_4 > B_1$.

For B_3, there is a section with radius > b and hence it contributes less than the semicircular section of radius b does for B_2. Thus $B_3 < B_2$.

4. Two coils X and Y having the same number of turns, carrying the same current and in the same sense are arranged coaxially so that they subtend the same solid angle at point O. If the smaller coil is midway between the larger coil and the point O, then the ratio of the magnetic fields at O due to the two coils is

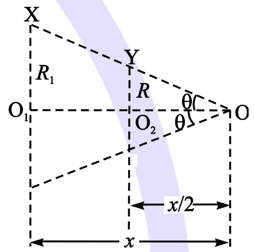


(A) 1 (B) 4 (C) 2 (D) 8

Ans (C)

It is obvious from the diagram that

$$\tan\theta = \frac{R_1}{x} = \frac{R}{\frac{x}{2}} \Rightarrow R_1 = 2R$$



The magnetic field at O due to coil X is

$$B_1 = \frac{\mu_0 I R_1^2}{2[R_1^2 + x^2]^{\frac{3}{2}}} = \frac{\mu_0 I \times 4R^2}{2[4R^2 + x^2]^{\frac{3}{2}}}$$

The magnetic field at O due to coil Y is

$$B_2 = \frac{\mu_0 I R^2}{2\left[R^2 + \frac{x^2}{4}\right]^{\frac{3}{2}}} = \frac{\mu_0 I R^2 \times 4^{\frac{3}{2}}}{2[4R^2 + x^2]^{\frac{3}{2}}}$$

$$\therefore \frac{B_1}{B_2} = \frac{4}{4^{\frac{3}{2}}} = \frac{4}{2^3} = \frac{4}{8} = \frac{1}{2} \Rightarrow \frac{B_2}{B_1} = 2$$

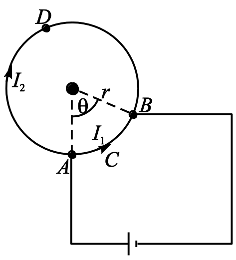
5. A battery is connected between two points A and B on a uniform conducting ring of radius r and resistance R. One of the arcs AB of the ring subtends an angle θ at the centre. The value of the magnetic field at the centre due to the current in the ring is

(A) proportional to $2(2\pi - \theta)$ (B) inversely proportional to R

(C) zero, only if $\theta = 2\pi$ radian (D) zero, for all values of θ.

Ans (D)

The situation is shown in figure.



$$I \propto \frac{1}{\text{resistance of arc}}$$

$$\frac{I_2}{I_1} = \frac{R_{ACB}}{R_{ADC}} = \frac{l_{ACB}}{l_{ADC}}$$

$$= \frac{r\theta}{r(2\pi - \theta)} = \frac{\theta}{(2\pi - \theta)}$$

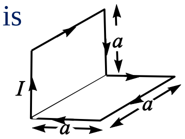
The magnetic fields at the centre due to the arcs ACB and ADC are given by

$$B_1 = \frac{\mu_0 I_1 \theta}{2r \times 2\pi} \square \quad \text{and} \quad B_2 = \frac{\mu_0 I_2 (2\pi - \theta)}{2r \times 2\pi} \otimes$$

$$\frac{B_1}{B_2} = \frac{I_1}{I_2} \times \frac{\theta}{2\pi - \theta} = \frac{2\pi - \theta}{\theta} \times \frac{\theta}{2\pi - \theta} = 1$$

$\therefore$ Resultant magnetic field is zero for all values of θ.

6. The magnitude of magnetic moment of the current loop shown in the figure is



(A) Ia^2 (B) $\sqrt{2}\ Ia^2$

(C) zero (D) $\dfrac{\sqrt{3}}{2}\text{Ia}^2$

Ans (B)

The loop can be divided into two square loops.

The magnetic moments of loops are perpendicular to each other.

For each square loop, $M = I\ a^2$,

we have $M_1 = M_2 = Ia^2$

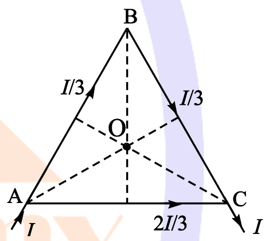
The net magnetic moment is

$$M = \sqrt{M_1^2 + M_2^2} = \sqrt{2}\,M_1 = \sqrt{2}\,Ia^2$$

7. A conducting wire of uniform cross-section is bent to form an equilateral triangle ABC of side L. A current I enters at A and leaves at C. The magnetic field at the centroid O of the triangle is

(A) $2\sqrt{3}\dfrac{\mu_0}{4\pi}\dfrac{I}{L}$ (B) $\dfrac{\mu_0}{4\pi}\dfrac{I}{L}$ (C) $\sqrt{3}\dfrac{\mu_0}{4\pi}\dfrac{I}{L}$ (D) zero.

Ans (D)



The field at a point due to a straight conductor of finite length is $B = \dfrac{\mu_0 I}{4\pi r}[\sin\alpha_1 + \sin\alpha_2]$

$$B_{AB} = B_{BC} = \frac{\mu_0}{4\pi}\frac{(I/3)}{(L/2\sqrt{3})}[\sin 60° + \sin 60°] = \frac{\mu_0}{4\pi}\frac{2I}{L}$$

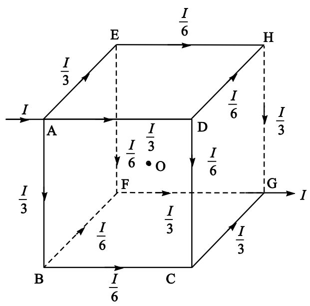
both directed normally it to the plane of loop.

Similarly, $B_{AC} = \dfrac{\mu_0}{4\pi}\dfrac{(2I/3)}{(L/2\sqrt{3})}[\sin 60° + \sin 60°] = \dfrac{\mu_0}{4\pi}\dfrac{4I}{L}$ directed normally out of the plane of loop. Resultant magnetic field at the centroid O is

$B = B_{AB} + B_{BC} - B_{AC} = 0$

8. A uniform metallic wire forms the edges of a cube of length l. A current I enters at one edge of the cube and leaves from the diagonally opposite edge. The magnitude of the magnetic field at the centre of the cube is

(A) zero (B) $\dfrac{\mu_0}{4\pi}\left(\dfrac{24}{\sqrt{3}}\right)\dfrac{i}{l}$ (C) $\dfrac{12}{\sqrt{3}}\dfrac{\mu_0}{4\pi}\dfrac{i}{l}$ (D) $\dfrac{6}{\sqrt{3}}\dfrac{\mu_0}{4\pi}\dfrac{i}{l}$



Ans (A)

The given system exhibits symmetry with respect to the diagonally opposite corners A and G. The current distribution is similar in the two halves of the cube with AG as reference. These current distributions produce fields of same magnitude and opposite directions at the centre of the cube.

Hence, the resultant magnetic field at the centre of the cube is zero.

9. An infinitely long conductor PQR is bent to form a right angle as shown in figure. A current I flows through PQR. The magnetic field due to this current at the point M is B_1. Now, another infinitely long straight conductor QS is connected at Q so that the current is $\left(I/2\right)$ in QR as well as QS, the current in PQ remaining unchanged. The magnetic field at M is now B_2. The ratio $\dfrac{B_1}{B_2}$ is given by

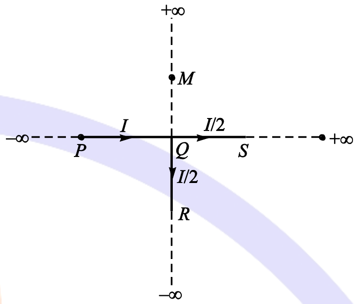
(A) $\frac{1}{2}$ (B) 1 (C) $\frac{2}{3}$ (D) 2

Ans (C)

The magnetic field at *M* due to QR is zero in both cases. When QS carries current $\frac{I}{2}$, the magnetic field at *M* due to QS is

$B' = \frac{1}{2} \times$ Magnetic field due to PQ carrying current *I*

$= \frac{1}{2} B_1$

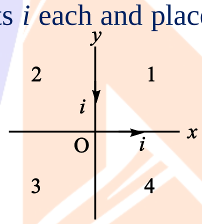


Total field at *M* is

$B_2 = B_1 + B' = B_1 + \frac{1}{2} B_1 = \frac{3}{2} B_1$

or $\frac{B_1}{B_2} = \frac{2}{3}$

10. Figure shows two long straight wires carrying currents *i* each and placed perpendicular to each other. The resultant magnetic field is zero



(A) in quadrant 1 and 2

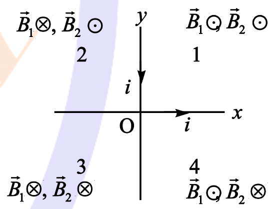
(B) in quadrant 2 and 4

(C) in quadrant 3 and 4

(D) at the point of intersection.

Ans (B)

Let $\vec{B}_1$ and $\vec{B}_2$ represent the magnetic field at any point due to currents in the vertical and the horizontal wires respectively.



Application of the Fleming's right hand rule gives the direction of magnetic field at different points.

Here $B_1 = B_2$ (in magnitude)

From figure, it follows that the fields cancel each other in quadrants (2) and (4). Hence, in the given context choice (B) is correct.

11. A current of 25 A flows through an overhead power cable from the North to South direction. The magnitude and direction of magnetic field at a point 5 m below the cable is

(A) 10^{-6} T towards east (B) 10^{-6} T towards west

(C) 10^{-5} T towards north (D) 10^{-5} T towards south

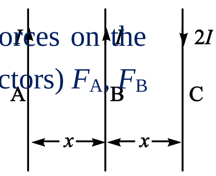
Ans (A)

Magnitude of the magnetic field is given by

$$B = \frac{\mu_0 I}{2\pi r} = \frac{4\pi \times 10^{-7} \times 25}{2\pi \times 5} = 10^{-6} \text{T}$$

From the right hand clasp rule, it follows that direction of *B* is towards east.

12. Three conductors are arranged as shown in the diagram. If the magnitude of the forces on the conductors A, B and C are (assume *x* to be small compared to the length of the conductors) F_A, F_B and F_C respectively, then



(A) $F_A = F_B > F_C$ (B) $F_A = 0, F_C \neq 0, F_B > F_C$

(C) $F_A = F_B = 0, F_B > F_C$ (D) $F_A = 0, F_B \neq 0, F_C > F_B$

Ans (D)

$$F_A = \frac{\mu_0}{2\pi}\left[\frac{I\times I}{x} - \frac{I\times 2I}{2x}\right] = 0$$

$$F_B = \frac{\mu_0}{2\pi}\left[\frac{I\times I}{x} - \frac{I\times 2I}{x}\right] = -\frac{\mu_0 I^2}{2\pi x}$$

$$F_C = \frac{\mu_0}{2\pi}\left[\frac{I\times 2I}{2x} + \frac{I\times 2I}{x}\right] = \frac{3\mu_0 I^2}{4\pi x}$$

13. A solenoid has a length 1 m and inner diameter 4 cm and it carries a current of 5 A. It consists of five close packed layers, each with 800 turns along its length. The magnitude of the magnetic field at the centre is nearly equal to

(A) zero (B) 25 mT (C) 5 mT (D) 1 mT

Ans (B)

Number of turns per unit length, $n = \frac{5\times 800}{1} = 4000$ turns per meter.

Length, $L \gg d$. The solenoid is long and can be treated as an ideal solenoid.

The magnetic field at the centre is given by $B = \mu_0 nI = (4\pi \times 10^{-7}) \times (5\times 4000)$ = 25 mT.

14. *When a proton, a deuteron and an α-particle are projected into a uniform magnetic field at right angles to the field, the radii of their respective paths are found to be in the ratio $1:\sqrt{2}:1$. The respective accelerating potentials for providing the required velocities are in the ratio

(A) $1:\sqrt{2}:1$ (B) 1:1:2 (C) 1:2:1 (D) 2 : 2 : 1

Ans (D)

Work done by the accelerating potential is equal to the kinetic energy gained by the charged particle in the electric field. Given: $r_p : r_d : r_\alpha = 1:\sqrt{2}:1$

We have, $r = \sqrt{\frac{2mqV}{qB}}$. For a given B, $\Rightarrow V \propto \frac{r^2 q}{m}$ $\therefore r \propto \sqrt{\frac{mV}{q}}$

$$V_p : V_d : V_\alpha = \frac{r_p^2 q_p}{m_p} : \frac{r_d^2 q_d}{m_d} : \frac{r_\alpha^2 q_\alpha}{m_\alpha} = \frac{1\times e}{m} : \frac{(\sqrt{2})^2\times e}{2m} : \frac{1^2\times 2e}{4m} = 2:2:1$$

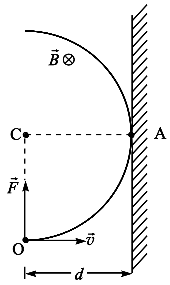
15. A particle with charge to mass ratio, $q/m = \alpha$ is shot with a speed v towards a wall at a distance d perpendicular to the wall. The minimum value of $\vec{B}$ that must exist in this region for the particle not to hit the wall is

(A) $\frac{v}{\alpha d}$ (B) $\frac{2v}{\alpha d}$ (C) $\frac{v}{2\alpha d}$ (D) $\frac{v}{4\alpha d}$.

Ans (A)

The situation is shown in the figure.

Let the particle projected at the point O, undergo deflection due to the applied magnetic field $\vec{B}$ in a direction normally inwards and let it just miss hitting the wall at A.



Then, $r = \frac{mv}{qB}$

For the particle not to hit the wall i.e., to just miss hitting the wall, $r = d \Rightarrow \frac{mv}{qB} = d$

$$B = \frac{mv}{qd} = \frac{v}{\alpha d} \qquad \dots (1)$$

16. A neutral atom which is at rest at the origin of the co-ordinate system emits an electron in the z- direction. The product ion is P. A uniform magnetic field exists in the positive x-direction.

(A) The electron and the ion P will move along circular paths of equal radii.

(B) The electron has same time period as that of the ion P

(C) The electron has same kinetic energy as that of the ion P

(D) The electron starts moving in a circle around the ion P.

Ans (A)

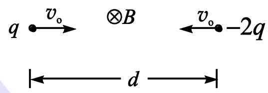
The total momentum of the system is conserved. Hence, the electron and the ion P move in opposite directions with equal momenta.

Radius of the circular path, $r = \frac{mv}{qB} = \frac{p}{eB}$

In the given situation, *p*, *e* and *B* are same for both the electron and the ion.

Hence, both the particles describe circles of same radius.

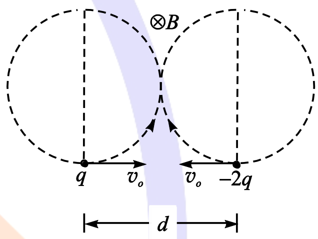
17. Two particles of masses *m* and 2*m* carrying charges *q* and −2*q* respectively are projected towards each other with the same speed *v* into a region of uniform magnetic field $\vec{B}$ directed normally inwards into the plane of the diagram. If *d* is the initial separation between the particles, then the maximum value of the speed *v* so that the particles do not collide, is (consider only the magnetic force of interaction on each).



(A) $\frac{qBd}{m}$ (B) $\frac{qBd}{2m}$ (C) $\frac{2qBd}{m}$ (D) $\frac{qBd}{4m}$

Ans (B)

Under the influence of the external uniform magnetic field, the two particles describe circular paths of radii r_1 and r_2 given by $r_1 = \frac{mv_0}{qB}$ and $r_2 = \frac{2mv_0}{2qB} = \frac{mv_0}{qB}$



Hence, $r_1 = r_2$

The particles do not collide if $d \geq 2r$, or $d \geq \frac{2mv}{qB}$

$\frac{qBd}{2m} \geq v$ or $v \leq \frac{qBd}{2m}$. Hence, the maximum speed of projection must be $\left(\frac{qBd}{2m}\right)$.

18. An electron and a proton enter a region of uniform magnetic field at right angles to it with the same linear momentum. Then

(A) the radius of the circular path of electron is less than that of the proton

(B) the radius of the circular path of electron is greater than that of the proton

(C) the radius of the circular path of electron is same as that of the proton

(D) both the proton and the electron move in opposite directions along a straight line.

Ans (C)

For a charged particle describing a circular path in a region of a uniform magnetic field, the centripetal force is provided by the force due to the magnetic field.

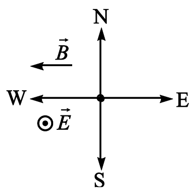
i.e., $\frac{mv^2}{r} = Bqv \Rightarrow r = \frac{mv}{Bq}$.

The radius of the proton path $r_p = \frac{m_p v_p}{Be}$.

The radius of the electron path $r_e = \frac{m_e v_e}{Be} \Rightarrow \frac{r_p}{r_e} = \frac{m_p v_p}{m_e v_e}$.

But it is given that the linear momentum (*mv*) of both the particles is same. Therefore $\frac{r_p}{r_e} = 1$. Thus, both the proton and the electron describe circular paths of same radii.

19. The figure shows four possible directions for the velocity $\vec{v}$ of a proton moving through a region of uniform electric field $\vec{E}$ and magnetic field $\vec{B}$. The direction of $\vec{v}$ so that the net force on the proton is zero is



(A) N (B) S (C) E (D) W

Ans (B)

$\vec{F}_{net} = q[\vec{E} + (\vec{v} \times \vec{B})] = 0 \Rightarrow \vec{E} = -(\vec{v} \times \vec{B})$

Since $\vec{E}$ is normally outwards, $\vec{v} \times \vec{B}$ is normally inwards. i.e., magnetic force $\vec{F}_m$ is directed normally inwards. The application of Fleming's left hand rule indicates that the velocity $\vec{v}$ is along south direction (S).

20. A charged particle with charge q enters a region of uniform and mutually orthogonal fields $\vec{E}$ and $\vec{B}$ with a velocity $\vec{v}$ perpendicular to both $\vec{E}$ and $\vec{B}$. The particle comes out without any change in magnitude or direction of its velocity. Then

(A) $\vec{v}=\frac{\vec{B}\times\vec{E}}{E^2}$ (B) $\vec{v}=\frac{\vec{E}\times\vec{B}}{B^2}$ (C) $\vec{v}=\frac{\vec{B}\times\vec{E}}{B^2}$ (D) $\vec{v}=\frac{\vec{E}\times\vec{B}}{B^2}$

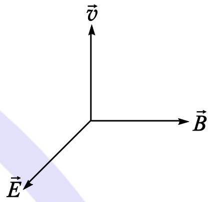
Ans (B)

As $\vec{E}$ and $\vec{B}$ are mutually perpendicular and $\vec{v}$ does not change.

$qE = qvB$ or $v=\frac{E}{B}$ … (1)

$\frac{E}{B}=\frac{EB\sin\theta}{B^2}=\frac{\vec{E}\times\vec{B}}{B^2}$ … (2)

$\therefore\ \vec{v}=\frac{\vec{E}\times\vec{B}}{B^2}$



21. A conductor AB carries a current i in a magnetic field $\vec{B}$. If $\overrightarrow{AB}=\vec{r}$ and the force on the conductor is $\vec{F}$, then

(A) $\vec{F}=i(\vec{r}\times\vec{B})$

(B) $\vec{F}=i(\vec{B}\times\vec{r})$

(C) $|\vec{F}|=i(\vec{r}\cdot\vec{B})$

(D) $\vec{F}$ is the resultant effect of the electric forces on the electrons in the conductor.

Ans (A)

Force on a current carrying conductor is $\vec{F}=i(\vec{r}\times\vec{B})$.

22. A long straight wire carrying current lies along the axis perpendicular to the plane of a metal ring. The conductor will

(A) exert a force on the ring if the ring carries a current.

(B) exert a force on the ring if the ring has a static charge distributed uniformly on the rim of the ring.

(C) exert a force on the ring if the ring has a static charge distributed non-uniformly on the rim of the ring.

(D) not exert any force on the ring.

Ans (D)

The straight wire carrying current produces a magnetic field $\vec{B}$ at every point on the rim of the ring. But this field $\vec{B}$

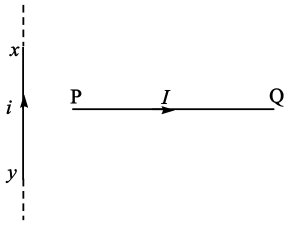
is along the current element $i\,\vec{dl}$ at every point on the ring, where i is the current in the ring.

Mechanical force on each element of the ring is zero.

$\vec{F}=i\vec{dl}\times\vec{B}=0$ as $\vec{dl}\times\vec{B}$ is zero

Even if the ring is charged, the force is zero as the magnetic field does not interact with static charges irrespective of the nature of their distributions.

23. A conductor PQ of length L carrying a current I is placed perpendicular to a long straight conductor xy carrying a current I, as shown in the figure. The force on PQ will be



(A) upwards (B) downwards

(C) to the right (D) to the left.

Ans (A)

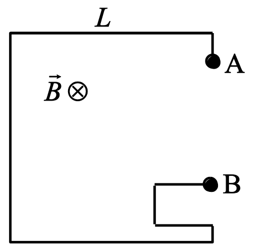
The magnetic field at any point on the wire PQ due to the current i in the wire XY is directed normally into the plane of the diagram.

Now applying Fleming's left hand rule, we notice that the mechanical force on PQ is directed upwards.

24. A bent wire AB carrying a current I is placed in a region of uniform magnetic field $\vec{B}$. The force on the wire AB is

(A) *BIL* (B) $\frac{3}{2}$ *BIL*

(C) zero (D) $\frac{BIL}{2}$.

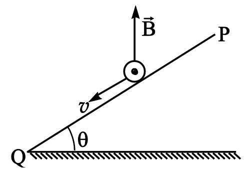


Ans (D)

$\vec{F} = I(\vec{l} \times \vec{B})$. Here $\vec{l}$ is directed from end *A* to end *B* of the wire.

Here $|\vec{l}| = \frac{L}{2}$ and θ = 90°. ∴ $F = I \times \frac{L}{2} \times B = \frac{BIL}{2}$

25. A copper rod of length *L* and mass *m* is sliding down a smooth inclined plane of inclination θ with a constant speed *v*. A current *I* is flowing in the conductor perpendicular to the plane of diagram inwards. A vertically upward magnetic field $\vec{B}$ exists in this region. The magnitude of the required magnetic field $\vec{B}$ is

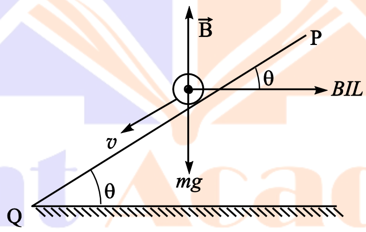


(A) $\frac{mg}{IL}\sin\theta$ (B) $\frac{mg}{IL}\cos\theta$

(C) $\frac{mg}{IL}\tan\theta$ (D) $\frac{mg}{IL\sin\theta}$

Ans (C)

Magnetic force on the rod, $F_m = BIL$. It acts in the direction as shown in figure. The rod will move with a constant speed if the net force on the rod is zero.

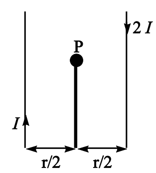


BIL cos θ = *mg* sin θ or $B = \frac{mg}{IL}\frac{\sin\theta}{\cos\theta} = \frac{mg}{IL}\tan\theta$.

26. Two very long straight parallel wires carry currents *I* and 2*I* in opposite directions. The distance between the wires is *r*. At a certain instant of time a point charge *q* is located at a point equidistant from the two wires in the plane of the wires. Its instantaneous velocity $\vec{v}$ is perpendicular to this plane. The force due to the magnetic field acting on the charge at this instant is

(A) zero (B) $\frac{3\mu_0}{2\pi}\frac{Iqv}{r}$ (C) $\frac{\mu_0}{\pi}\frac{Iqv}{r}$ (D) $\frac{\mu_0}{2\pi}\frac{Iqv}{r}$

Ans (A)



The field acts parallel to the direction of motion of the charged particle. Hence, the force on it is zero.

Force on charged particle is

$F = qvB \sin\theta = qvB \times 0 = 0$.

27. An electron moves parallel to a current carrying conductor with a velocity 10^7 ms^{-1}. If the conductor carries a current of 10 A, then the magnitude of the force experienced by the electron is

(A) 4×10^{-8} N (B) 6.2×10^{-16} N (C) 3.6×10^{-18} N (D) 8×10^{-17} N.

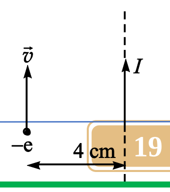
Ans (D)

Force experienced by the electron $F = Bqv \sin\theta$.

The magnetic field at a distance *r* from a straight conductor carrying current *I* is, $B = \frac{\mu_0 I}{2\pi r}$

The magnetic field exerts a force on the electron given by $F = evB\sin\theta$

Here θ = 90°,



$\therefore\ F = evB = ev \cdot \dfrac{\mu_0 I}{2\pi r}$

$F = \dfrac{4\pi \times 10^{-7} \times 10 \times 1.6 \times 10^{-19} \times 10^{7}}{2\pi \times 4 \times 10^{-2}}$

$= 8 \times 10^{-17}$ N.

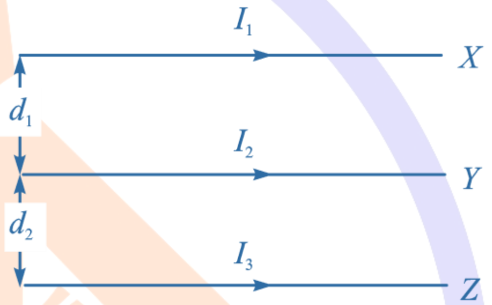
28. Three long straight wires X, Y and Z are connected parallel to each other across a battery of negligible internal resistance. The resistances of the three wires are in the ratio 1 : 2 : 3. If the net force experienced by the middle wire Y is zero, then the ratio of the distances of the middle wire from the other two wires is

(A) 3 : 1 (B) 1 : 2 (C) 2 : 3 (D) 3 : 4

Ans (A)

The wires X, Y and Z are in parallel.

$\therefore I_1 : I_2 : I_3 = \dfrac{1}{R_1} : \dfrac{1}{R_2} : \dfrac{1}{R_3} = 1 : \dfrac{1}{2} : \dfrac{1}{3}$



$\Rightarrow F_Y = 0$

$\Rightarrow F_{YX} = F_{YZ}$ … (in magnitude)

$\dfrac{\mu_0}{2\pi} \dfrac{I_1 I_2}{d_1} = \dfrac{\mu_0}{2\pi} \dfrac{I_2 I_3}{d_2}$

$$\frac{I_1}{d_1} = \frac{I_3}{d_2} \Rightarrow \frac{d_1}{d_2} = \frac{I_1}{I_3} = \frac{\left(\dfrac{I}{1+\frac{1}{2}+\frac{1}{3}}\right)\times 1}{\left(\dfrac{I}{1+\frac{1}{2}\times\frac{1}{3}}\right)\times 3} = \frac{1}{3}$$

29. A circular loop of area 0.02 m^2 carrying a current of 10 A is held with its plane perpendicular to a uniform magnetic field, 0.2 T. The torque acting on the loop is

(A) 0.01 N m (B) 0.001 N m (C) zero (D) 0.8 N m

Ans (C)

$\tau = nIAB \sin\theta$

$\tau = nIAB \sin(0) = 0$

30. A wire of length l is bent in the form of a circular loop and is suspended in a region of a uniform magnetic field B. When a steady current I is passed through the loop, the maximum torque experienced by it is

(A) $\dfrac{Il^2B}{4\pi^2}$ (B) $\dfrac{BIl^2}{4\pi}$ (C) $4\pi^2 Il^2 B$ (D) $\dfrac{I}{4\pi B l^2}$

Ans (B)

The torque experienced by the loop $\tau = BIA \sin\theta$. The maximum torque experienced $\tau_{max} = BIA$.

Length of the loop $l = 2\pi R$. $\Rightarrow R = \dfrac{l}{2\pi}$.

Area of the loop $A = \pi R^2 = \dfrac{\pi l^2}{4\pi^2} = \dfrac{l^2}{4\pi}$

Torque, $\tau_{max} = BIA = \dfrac{BIl^2}{4\pi}$

31. The coil of a suspended coil galvanometer has very high resistance. When a momentary current is passed through the coil, it

(A) gets deflected and comes to rest slowly

(B) shows a steady deflection

(C) oscillates with the same amplitude

(D) oscillates with the decreasing amplitude.

Ans (D)

When a momentary current is passed, the coil is subjected to a sudden, unbalanced deflecting couple. Gradually under the action of the restoring couple, the coil comes to rest after executing several oscillations with decreasing amplitude.

32. A metal wire is bent to form a square loop of side L. It carries a current i and is placed in a region of a uniform magnetic field normal to the field $\vec{B}$. If the shape of the loop is slowly changed to a circle without changing its length, the amount of work done is

(A) $iBL^2\left(1-\frac{4}{\pi}\right)$ (B) $iBL^2\left(1+\frac{4}{\pi}\right)$ (C) $iBL^2\left(1-\frac{1}{4\pi}\right)$ (D) zero

Ans (A)

Work done, $W=-(U_f-U_i)$

$$=-(M_fB-M_iB)=-B(iA_f-iA_i)$$

$$=-iB(A_f-A_i)=-iB(\pi R^2-L^2)$$

$$=-iB\left(\pi\frac{4L^2}{\pi^2}-L^2\right)=-iBL^2\left(\frac{4}{\pi}-1\right)$$

$$W=iBL^2\left(1-\frac{4}{\pi}\right)$$

33. The sensitivity of a suspended coil galvanometer depends on

(A) moment of inertia of the coil

(B) the deflection θ

(C) the horizontal component B_H of earth's magnetic field

(D) the torsional constant of the suspension wire and the spring.

Ans (D)

The expression for current flowing through a suspended coil galvanometer is $I=\left(\frac{C}{nBA}\right)\theta$ or current sensitivity $\frac{I}{\theta}=\left(\frac{C}{nBA}\right)$. For a given coil, $\frac{I}{\theta}$ depends on C, the torsional constant or the couple per unit twist of the suspension wire.

34. Two moving coil galvanometers 1 and 2 are with identical field magnets and suspension torque constants, but with coils of different number of turns N_1 and N_2, area per turn A_1 and A_2 and resistances R_1 and R_2. When they are connected in series in the same circuit, they show deflection θ_1 and θ_2.

Then $\left(\frac{\theta_1}{\theta_2}\right)$ is

(A) $\left(\frac{A_1N_1}{A_2N_2}\right)$ (B) $\left(\frac{A_1N_2}{A_2N_1}\right)$ (C) $\left(\frac{A_1R_2N_1}{A_2R_1N_2}\right)$ (D) $\left(\frac{A_1R_1N_1}{A_2R_2N_2}\right)$

Ans (A)

$$I=\frac{K}{NBA}\theta$$

Given that $I_1=I_2$

$$\therefore \frac{K\theta_1}{N_1BA_1}=\frac{K\theta_2}{N_2BA_2}$$

So $\frac{\theta_1}{\theta_2}=\frac{A_1N_1}{A_2N_2}$

35. If an ammeter is to be used in place of a voltmeter, then we must connect with the ammeter

(A) a low resistance in parallel (B) a high resistance in parallel

(C) a high resistance in series (D) a low resistance in series

Ans (C)

An ammeter can be converted into a voltmeter by connecting a high resistance in series with it.

36. A voltmeter of range (0V □ 30 V) is to be connected to a voltage line of 150 V. The maximum current that the voltmeter can withstand is 5 mA. In order to connect the voltmeter safely to the voltage line, the series resistance required is

(A) 240 kΩ (B) 24 kΩ (C) 2.4 kΩ (D) 240 Ω

Ans (B)

The resistance to be connected in series is given by $R_s = \frac{V}{I} - R$. and $I = 5$ mA. The resistance of the voltmeter, $R = \frac{V'}{I} = \frac{30}{5\times10^{-3}} = 6 \times 10^3\Omega$. V′ is the line voltage to be measured (new range of the voltmeter).

$R_s = \frac{150}{5\times10^{-3}} - 6 \times 10^3 = 24 \times 10^3\ \Omega$.

37. The resistance of a galvanometer is 50 Ω and it requires 2 μA per two division deflection. The value of the shunt required in order to convert a galvanometer into ammeter of range 5 A is (The number of divisions on the galvanometer scale on one side is 30)

(A) 0.2 Ω (B) 0.002 Ω (C) 3×10^{-4} Ω (D) 4×10^{-6} Ω

Ans (C)

The shunt S to be connected is given by

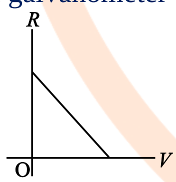
$$S = \frac{I_g G}{I - I_g}$$

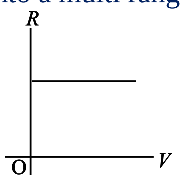
$$I_g = \left(\frac{I}{\theta}\right) \times N = \left(\frac{2\times10^{-6}}{2}\right) \times 30$$

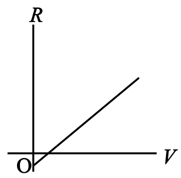
$\Rightarrow I_g = 30 \times 10^{-6}$ A.

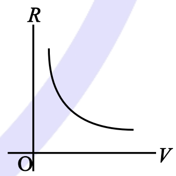
$$\therefore S = \frac{30\times10^{-6}\times50}{5-30\times10^{-6}} \cong 3 \times 10^{-4}\ \Omega$$

38. Of the following graphs, the one which shows the variation of the series resistance to be connected with a moving coil galvanometer so as to convert it into a multi range voltmeter is

(A) 

(B) 

(C) 

(D) 

Ans (C)

$R = \frac{V}{I_g} - G$ is the series resistance required for conversion into voltmeter of higher range.

(Compare with $y = mx + C$)

39. An α particle and a proton having equal velocity are moving inside a uniform magnetic field. The field is perpendicular to the direction of the velocity for both particles. Their radii r_α and r_p are in the ratio (assume $m_\alpha = 4 m_p$).

(A) $\frac{r_\alpha}{r_p} = \frac{1}{2}$ (B) $\frac{r_\alpha}{r_p} = \frac{1}{4}$ (C) $\frac{r_\alpha}{r_p} = \frac{2}{1}$ (D) $\frac{r_\alpha}{r_p} = \frac{4}{1}$

Ans (C)

We have the radius of the circular orbit given by $r = \frac{mv}{qB}$

$r_\alpha = \frac{(4m_p)v}{(2e)B}$ and $r_p = \frac{m_p v}{eB}$ $\therefore \frac{r_\alpha}{r_p} = \frac{2}{1}$

40. A uniform magnetic field is acting at an angle θ with respect to the direction of velocity (v) of a particle of charge q and mass m. The pitch of the helical path is

(A) $\frac{2\pi m v}{qB}\sin\theta$ (B) $\frac{2\pi m v}{qB}\cos\theta$ (C) $\frac{qB}{2\pi m v}\sin\theta$ (D) $\frac{qB}{2\pi m v}\cos\theta$

Ans (B)

For the motion of the particle, $\frac{mv^2}{r} = qvB \quad \therefore r = \frac{mv}{qB}$

By the time, a charged particle completes one circular motion, due to the component of velocity $v\cos\theta$ along the field, the charged particle moves through a distance namely the pitch.

$\therefore$ Pitch, $\Delta x = T \cdot v\cos\theta$

$$= \frac{2\pi r}{v} v\cos\theta$$

$$\Delta x = 2\pi\left(\frac{mv}{qB}\right)\cos\theta \;;\; \Delta x = \left(\frac{2\pi m v}{qB}\right)\cos\theta$$

Each of the following questions consists of a Statement−I and a Statement−II. Examine both of them and select one of the options using the following codes:

(A) Statement-I and Statement-II are true and Statement-II is the correct explanation of Statement-I.

(B) Statement-I and Statement-II are true, but Statement-II is not the correct explanation of Statement -I

(C) Statement-I is true, but Statement -II is false

(D) Statement-I is false, but Statement -II is true

41. **Statement-I:** The deflection in the galvanometer is directly proportional to the current passing through it.

Statement-II: The magnetic field in which the coil of galvanometer is suspended is radial.

(A) A (B) B (C) C (D) D

Ans (A)

Both assertion and reason are correct and reason is correct explanation of assertion as radial magnetic field helps to make the scale of galvanometer linear.

42. **Statement-I:** We can increase the range of an ammeter but cannot decrease the range.

Statement-II: Minimum range of an ammeter is fixed.

(A) A (B) B (C) C (D) D

Ans (A)

A suitable shunt resistance can be used in parallel with the ammeter to increase its range. But its range cannot be decreased as shunt cannot be made negative. The reason is true and explains the assertion correctly.

43. **Statement-I:** An ammeter connected in **parallel** with a resistance may get damaged.

Statement-II: An ammeter has low resistance.

(A) A (B) B (C) C (D) D

Ans (A)

An ammeter has low resistance. When an ammeter is connected in parallel with a resistance, the effective resistance of the circuit decreases. As a result, current in the circuit increases, which may damage the ammeter.

44. **Statement-I:** A charged particle is accelerated by a potential difference *V*. It then enters perpendicularly to a uniform magnetic field. It moves in a circle. Its angular momentum about centre is say *L*. Now if V is doubled, *L* is also doubled.

Statement-II: If *V* is doubled, kinetic energy is doubled and therefore, *L* is also doubled.

Ans (B)

NCERT LINE BY LINE QUESTIONS

1. A current element $\Delta l = dx\hat{i}$ (where *dx* = 1 cm) is placed at the origin and carries a large current of 10 A. The magnetic field on y-axis at distance of 50 cm from it is [NCERT Pg. 148)

(a) 2×10^{-8}T (b) 2×10^{-5}G (c) 4×10^{-8}T (d) 3×10^{-5}G

2. Consider a tightly wound 100 turn coil of radius 12 cm carrying current of 10 A. What is magnetic field at centre of this coil. [NCERT Pg. 146]

(a) 1.2×10^{-3}T (b) 5.2×10^{-3}T (c) 4.6×10^{-5}T (d) 1.9×10^{-6}T

3. A straight wire carrying current of **15** A is bent into a semicircular arc of radius **2.5** cm. The magnetic field at the centre of semicircular arc is [NCERT Pg. 150]

(a) 1.88×10^{-4}T (b) 2.6×10^{-4}T (c) 3.77×10^{-4}T (d) 5.2×10^{-4}T

4. Consider a tightly wound 200 turns coil of radius 10 cm carrying current of 10 A. The magnitude of magnetic field at the centre of the coil is [NCERT Pg. 151]

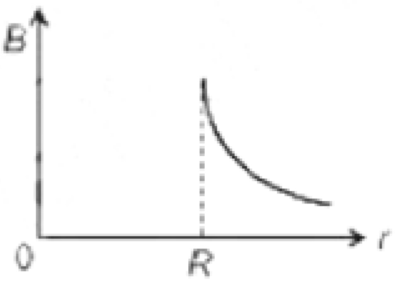
(a) $2\pi\times10^{-4}$T (b) $4\pi\times10^{-3}$T (c) $6\pi\times10^{-4}$T (d) $3\pi\times10^{-3}$T

5. A long straight wire of circular cross-section of radius 5 cm is carrying a steady current of 20 A, uniformly distributed over its cross-section. The magnetic field induction at 2 cm from the axis of the wire is

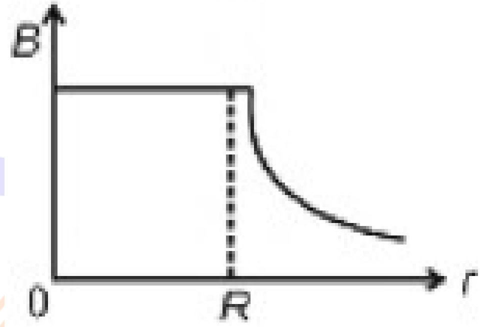
[NCERT Pg. 149]

(a) 1.6×10^{-4}T (b) 2.8×10^{-2}T (c) 3.3×10^{-6}T (d) 3.2×10^{-5}T

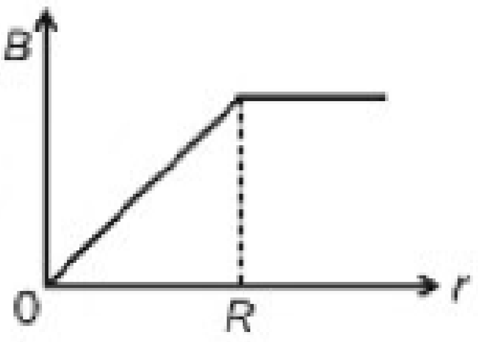
6. A long straight cylindrical wire carries current I and current is uniformly distributed across cross-section of conductor. Figures below shows a plot of magnitude of magnetic field with distance from centre of the wire. The correct graph is [NCERT Pg. 150]



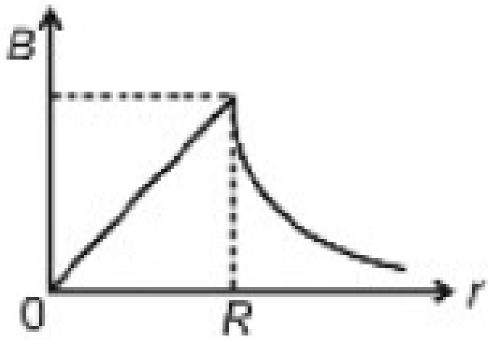
(a)



(b)



(c)



(d)

7. A closely wound solenoid 80 cm long has 5 layers of winding of 400 turns each. The diameter of solenoid is 1.8 cm. If it carries current of 8 A then magnitude of magnetic field intensity inside solenoid near its centre is [NCERT Pg. 173]

(a) 1.62×10^{-4}T (b) 25.13×10^{-3}T (c) 3.1×10^{-2}T (d) 16.8×10^{-3}T

8. A circular coil of 30 turns and radius 8 cm carries a current of 6 A. It is suspended in a uniform horizontal magnetic field of 1.0 T. The field lines make an angle of 60° with the normal of the coil. The magnitude of counter torque that must be applied to prevent the coil from turning is [NCERT Pg. 169]

(a) 3.133 Nm (b) 0.236 N m (c) 30.8 N m (d) 35 N m

9. In a chamber, a uniform magnetic field of 1.2 T is maintained. An electron is shot into the field with a speed of $3.2 \text{ X } 10^6$ m s^{-1} normal to the field. The radius of circular orbit in which it starts circular path is ($m_0 = 9.1 \text{ X } 10^{-31}$ kg) [NCERT Pg. 169]

(a) 15.16 μm (b) 627 μm (c) 12.42 μm (d) 22.4 μm

10. Two moving coil galvanometers M_1 and M_2 have the following particulars. $N_1 = 30$, $B_1 = 0.25$ T, $A_1 = 7.2 \text{ X } 10^{-3}$ m², $G_1 = 10\Omega$ and $N_2 = 60$, $B_2 = 0.50$ T, $A_2 = 1.8 \text{ X } 10^{-3}$ m², $G_2 = 5\Omega$ respectively. The spring constants are identical to both galvanometers. The ratio of their current sensitivity is [NCERT Pg. 173]

(a) 1:1 (b) 2:1 (c) 4 : 1 (d)1:4

11. A toroid ring has inner radius 21 cm and outer radius 23 cm in which 4400 turns of wire are wound. If the current in the wire is 10 A, then magnetic field inside the core of the toroid will be [NCERT Pg. 170]

(a) 4.4×10^{-4}T (b) 4×10^{-2}T (c) 6.6×10^{-4}T (d) 12.6×10^{-3}T

12. Two concentric circular coils X and Y of radius 20 cm and 25 cm respectively lie in the same vertical plane. Coil X has 40 turns and coil Y has 100 turns. If coil X and Y carries currents of 18 A each but in opposite
sense, the net magnetic field due to the coils at their centre is [NCERT Pg. 170]
(a) 3.12×10^{-4}T (b) 1.2×10^{-5}T (c) 7.2×10^{-4}T (d) 2.26×10^{-3}T

13. A galvanometer has resistance of $60\,\Omega$. It is converted in to an ammeter by connecting a shunt resistance of $1.2\,\Omega$. Its range becomes [NCERT Pg. 172]
(a) 68 (b) 50 (c) 51 (d) 60

14. To convert a galvanometer into a voltmeter of large range, we connect a resistance with galvanometer. The resistance [NCERT Pg. 165]
(a) Is connected in parallel and of higher value
(b) Is connected in series and of lower value
(c) Is connected in parallel and of lower value
(d) Is connected in series and of higher value

15. Magnetic moment associated with an electron moving at speed *v* in a circular orbit of radius *r* is (in magnitudes) [NCERT Pg. 162]
(a) evr (b) $\frac{evr}{2}$ (c) $\frac{evr}{4}$ (d) $\frac{ev^2}{2r}$

16. The horizontal component of earth's magnetic field at a certain place is 3.2 x 10^{-5} T and field is directed from south to North. A long straight conductor is carrying a current of 3 A. What is force per unit length experienced by it when it is placed on horizontal table and current in wire is from west to east? [NCERT Pg. 156]
(a) 9.6 X 10^{-6} Nm^{-1} upwards (b) 9.6 X 10^{-5} Nm^{-1}. downwards
(c) 3.6 X 10^{-5} Nm^{-1}, upwards (d) 9.6 X 10^{-5} Nm^{-1}, horizontal

17. Two long straight parallel wires A and B carrying current of 20 A and 10 A is same direction are separated by a distance of 5 cm. The force of 15 cm section of wire B is [NCERT Pg. 173]
(a) 1.5×10^{-3}N ,attractive (b) 1.6×10^{-4}N , repulsive
(c) 1.2×10^{-3}N, attractive (d) 1.2×10^{-4}N, attractive

18. A cyclotron's oscillatory frequency is 10 MHz. What should be the operating magnetic field for accelerating deuterons? [NCERT Pg. 146]
(a) 0.96 T (b) 1.52 T (c) 0.46 T (d) 1.32 T

19. A charge $q=1.6\times10^{-12}$ C moving with speed of v m s^{-1} crosses electric field $|\vec{E}|=6\times10^4$ Vm^{-1} and magnetic field $|\vec{B}|=1.2T$. The electric field and magnetic fields are crossed and velocity *v* is also perpendicular to both. If the charge particle crosses both fields undeflected, the value of v is [NCERT Pg. 140]
(a) 7.2×10^5 (b) 7.2×10^4 (c) 5×10^5 (d) 5×10^4

20. A proton is moving with speed of 2 x 10^5 m s^{-1} enters a uniform magnetic field *B* = 1.5 T. At the entry velocity vector makes an angle of 30° to the direction of the magnetic field. The pitch of helical path it
describes is nearly [NCERT Pg. 138]

(a) 6.25 mm (b) 4.37 mm (c) 7.25 mm (d) 1.67 mm

NCERT BASED PRACTICE QUESTIONS

1. A magnetic field line is used to find the direction of
(a) south – north (b) a bar magnet
(c) a compass needle (d) magnetic field

2. An electric current passes through a straight wire in the direction of south to north. Magnetic compasses are placed at points A and B as shown in the figure.

What is your observation?
(a) the needle will not deflect
(b) only one of the needles will deflect
(c) both the needles will deflect in the same direction
(d) the needles will deflect in the opposite directions

3. The magnetic field lines due to a straight wire carrying a current are
(a) straight (b) circular
(c) parabolic (d) elliptical

4. Magnetic field produced at the centre of a current carrying circular wire is
(a) directly proportional to the square of the radius of the circular wire
(b) directly proportional to the radius of the circular wire
(c) inversely proportional to the square of the radius of the circular wire
(d) inversely proportional to the radius of the circular wire

5. The magnetic field lines inside a long, current carrying solenoid are nearly
(a) straight (b) circular
(c) parabolic (d) elliptical

6.‘ A soft iron bar is introduced inside a current carrying solenoid. The magnetic field inside the solenoid
(a) will become zero (b) will decrease
(c) will increase (d) will remain unaffected

7. The direction of the force on a current-carrying wire placed in a magnetic field depends on
(a) the direction of the current
(b) the direction of the field
(c) the direction of current as well as field
(d) neither the direction of current nor the direction of field

8. The direction of induced curent is obtained by
(a) Fleming’s left-hand rule
(b) Maxwell’s right-hand thumb rule
(c) Ampere’s rule
(d) Fleming’s right-hand rule

9. Who first discovered the relationship between electricity and magnetism?

(a) Faraday (b) Newton
(c) Maxwell (d) Oersted

10.: In an electric motor, the energy transformation is from
(a) electrical chemical (b) chemical to light
(c) mechanical to electrical (d) electrical to mechanical

11. A commentator changes the direction of current in the coil of
(a) a DC motor
(b) a DC motor and an AC generator
(c) a DC motor and a DC generator
(d) an AC generator

12. ____Which of the following devices works on the principle of electromagnetic induction?
(a) Ammeter (b) Voltmeter
(c) Generator (d) Galvanometer

13. __A device used for measuring small currents due to changing magnetic field is known as
(a) galvanometer (b) ammeter
(c) voltmeter (d) potentiometer

14.: An electric generator actually acts as
(a) source of electric charge (b) source of heat energy
(c) an electromagnet (d) a converter of energy

15. Electromagnetic induction is the
(a) charging of a body with a positive charge
(b) production of a current by relative motion between a magnet and a coil
(c) rotation of the coil of an electric motor
(d) generation of magnetic field due to a current carrying solenoid

16. For making a strong electromagnet, the material of the core should be
(a) soft iron (b) steel
(c) brass (d) copper

17. Magnetic field inside a long solenoid carrying current is
(a) same at all points (uniform)
(b) different at poles and at the centre
(c) zero
(d) different at all points

18. You have a coil and a bar magnet. You can produce an electric current by
1. moving the magnet but not the coil
2. moving the coil but not the magnet
3. moving either the magnet or the coil
4. using another DC source

19.: A fuse in an electric circuit acts as a
1. current multiplication
2. voltage multiplication
3. power multiplier
4. safety device

20. The magnetic lines of force inside a current carrying solenoid are

1. along the axis and parallel to each other
2. perpendicular to the axis and parallel to each other
3. circular and do not intersect each other
4. circular and intersect each other

21. Who was the first person to notice the magnetic effect of electric current?
(a) Faraday (b) Ampere (c) Oersted (d) Volta

22. The magnetic field produced due to the current passing through a conductor is proportional to the
(a) electric current (b) conducting material
(c) length of conductor (d) diameter of conductor

23. 'The magnetic field produced at the center of a circular wire is proportional to and inversely proportional to
(a) radius of loop, current (b) current, radius of loop
(c) length of conductor, current (d) weight of conductor, current

24. The magnetic field of a solenoid is quite similar to that of
(a) a straight conductor (b) a horse-shoe magnet
(c) a bar magnet (d) any magnet

25. The principle of magnetic induction was given by
(a) Michael Faraday (b) Galileo
(c) Oersted (d) Ampere

26. The direction of a magnetic field is taken
(a) north to south and back (b) south to north and back
(c) north to south only (d) south to north only

27. In our domestic electric supply we use following three colours of wire.
(a) red, blue, green (b) red, yellow, blue
(c) red, black, green (d) black, green, yellow

28. The magnetic field due to electric current in a conductor is
(a) in the direction of electric current
(b) in the direction opposite to electric current
(c) circular around the conductor
(d) in the center of the conductor

29. Which device is used to convert electric energy into mechanical energy ?
(a) electric generator (b) solenoid
(c) electric motor (d) electric iron

30. The principle of electric generator is
(a) conversion of electrical energy into mechanical energy
(b) conversion of electrical energy into thermal energy
(c) conversion of mechanical energy into electrical energy
(d) conversion of electrical energy into light energy

31. Magnetic lines of force inside a solenoid are...
(a) from N to S (b) from S to N
(c) circular (d) Qintersect one another

32. A magnetized wire of magnetic moment M and length L is bent in the form of a semicircle of radius 'r'. The new magnetic moment is
(a) M (b) $M/2\pi$ (c) M/π (d) $2M/\pi$

33 In a hydrogen atom the electron is making 6.6×10^{15} revolutions per second around the nucleus in an orbit of radius 0.528 Å. The equivalent magnetic dipole moment is approximately (in Am^2)

(a) 10^{-10} (b) 10^{-15} (c) 10^{-2} (d) 10^{-25}

34. Two short magnets of dipole moments M and 2M are arranged on the table so that the axial line of the weaker magnet and the equatorial line of the stronger magnet are coinciding. If the separation between the magnets is 2d, what is the magnetic flux density midway between these magnets? Ignore the earth's magnetic field.

(a) $\mu_0 M/4\pi d^3$ (b) $3\mu_0 M/4\pi d^3$ (c) $(\mu_0 M/4\pi d^3)\sqrt{3}$ (d) $(\mu_0 M/4\pi d^3)\sqrt{3}$

35. An electron and a proton with the same momentum enter perpendicularly into a uniform magnetic field

a. Both particles will deflect equally,

b. The proton will deflect more than the electron,

c. The electron will deflect less than the proton

d. None

36. Two parallel beams of electrons moving in the same direction will

a. Repel each other,

b. Attract each other,

c. Neither attract nor repel each other.

d. none

37. When an electron moves in a magnetic field 'B' with velocity 'V' the force acting on it is perpendicular to

a .V but not to B, b. both V and B,

c. B but not V d. none

38. If an electron and proton enter into a magnetic field with the same velocity, the electron shall experience a/an force than the proton.

a. Greater, b. Lesser,

c. Equal d. none

39. Magnetism derives its name from a region in Asia Minor (Modern Turkey) where it was found in for form of certain iron core.

a. Magnesia b. Magnesium,

c. Electromagnetism d. None of these

40 . If a magnet is broken into two pieces, then

a. Two magnets are obtained,

b. North pole is obtained,

c. South pole is obtained,

d. One north pole and one south pole is obtained

41. A magnet can be demagnetized by

a. Heating,

b. By dropping it several time,

c. breaking into two pieces,

d. both heating and by dropping it several time

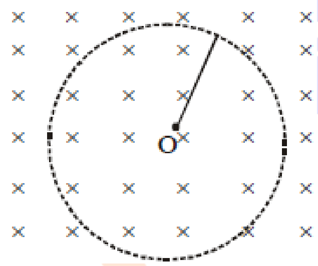
TOPIC WISE PRACTICE QUESTIONS

Topic 1: Motion of Charged Particle in Magnetic Field

1. A particle of mass *m* and charge *q* enters a magnetic field *B* perpendicularly with a velocity *v*. The radius of the circular path described by it will be

(1) Bq/mv (2) mq/Bv (3) mB/qv (4) mv/Bq

2. The figure shows a thin metalic rod whose one end is pivoted at point O. The rod rotates about the end O in a plane perpendicular to the uniform magnetic field with angular frequency w in clockwise direction. Which of the following is correct?



(1) The free electrons of the rod move towards the outer end.

(2) The free electrons of the rod move towards the pivoted end.

(3) The free electrons of the rod move towards the mid-point of the rod.

(4) The free electrons of the rod do not move towards any end of the rod as rotation of rod has no effect on motion of free electrons.

3. A charged particle enters into a magnetic field with a velocity vector making an angle of 30º with respect to the direction of magnetic field. The path of the particle is

(1) circular (2) helical (3) elliptical (4) straight line

4. A particle is projected in a plane perpendicular to a uniform magnetic field. The area bounded by the path described by the particle is proportional to

(1) the velocity (2) the momentum (3) the kinetic energy (4) None of these

5. An electric charge +*q* moves with velocity $\vec{v} = 3\hat{i} + 4\hat{j} + \hat{k}$ in an electromagnetic field given by $\vec{E} = 3\hat{i} + \hat{j} + 2\hat{k}$ and $\vec{B} = \hat{i} + \hat{j} - 3\hat{k}$ .The *y*-component of the force experienced by + *q* is :

(1) 11 *q* (2) 5 *q* (3) 3 *q* (4) 2 *q*

6. A straight steel wire of length *l* has a magnetic moment M. When it is bent in the form of a semi-circle its magnetic moment will be

(1) M (2) M/π (3) 2 M/π (4) Mπ

7. The magnetic force acting on a charged particle of charge $-2\,\mu$C in a magnetic field of 2T acting in y direction, when the particle velocity is $\left(2\hat{i}+3\hat{j}\right)\times10^{6}\,ms^{-1}$, is

(1) 4 N in z direction (2) 8 N in y direction (3) 8 N in z direction (4) 8 N in – z direction

8. A charged particle goes undeflected in a region containing electric and magnetic fields. It is possible that

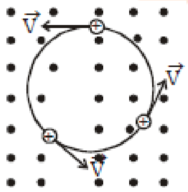
(1) $\vec{E}\parallel\vec{B}, \vec{v}\parallel\vec{E}$

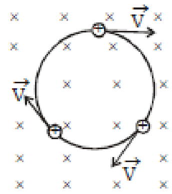
(2) $\vec{E}$ is not parallel to $\vec{B}$

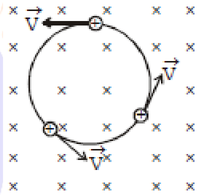
(3) $\vec{v}\parallel\vec{B}$ but $\vec{E}$ is not parallel to $\vec{B}$

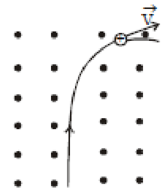
(4) $\vec{E}\parallel\vec{B}$ but $\vec{v}$ is not parallel to $\vec{E}$

9. A positively charged particle enters in a uniform magnetic field with velocity perpendicular to the magnetic field. Which of the following figures shows the correct motion of charged particle?

(1) 

(2) 

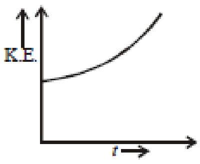
(3) 

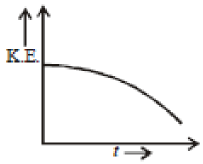
(4) 

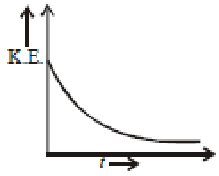
10. A thin circular wire carrying a current *I* has a magnetic moment *M*. The shape of the wire is changed to a square and it carries the same current. It will have a magnetic moment

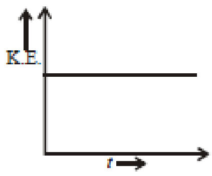
(1) M (2) $\frac{4}{\pi^2}M$ (3) $\frac{4}{\pi}M$ (4) $\frac{\pi}{4}M$

11. A charged particle enters in a magnetic field in a direction perpendicular to the magnetic field. Which of the following graphs show the correct variation of kinetic energy of the particle with time *t*?

(1) 

(2) 

(3) 

(4) 

12. An electron moves in a circular orbit with a uniform speed *v*. It produces a magnetic field *B* at the centre of the circle. The radius of the circle is proportional to

(1) $\sqrt{\frac{B}{v}}$ (2) $\frac{B}{v}$ (3) $\sqrt{\frac{v}{B}}$ (4) $\frac{v}{B}$

13. A proton moving with a velocity 3×10^5 m/s enters a magnetic field of 0.3 tesla at an angle of 30° with the field. The radius of curvature of its path will be (e/m for proton = 10^8 C/kg)

(1) 2 cm (2) 0.5 cm (3) 0.02 cm (4) 1.25 cm

14. A beam of electrons is moving with constant velocity in a region having simultaneous perpendicular electric and magnetic fields of strength 20 Vm^{-1} and 0.5 T respectively at right angles to the direction of motion of the electrons. Then the velocity of electrons must be

(1) 8 m/s (2) 20 m/s (3) 40 m/s (4) 1/40m/ s

15. A uniform magnetic field acts at right angles to the direction of motion of electron. As a result, the electron moves in a circular path of radius 2cm. If the speed of electron is doubled, then the radius of the circular path will be

(1) 2.0 cm (2) 0.5 cm (3) 4.0 cm (4) 1.0 cm

16. A proton moving with a constant velocity passes through a region of space without any change in its velocity. If E and B represent the electric and magnetic fields respectively, this region of space may not have

(1) E = 0, B = 0 (2) E = 0, B $\neq$ 0 (3) E $\neq$ 0, B = 0 (4) E $\neq$ 0, B $\neq$ 0

17. A charged particle (charge q) is moving in a circle of radius R with uniform speed v. The associated magnetic moment m is given by

(1) qvR^2 (2) $qvR^2/2$ (3) qvR (4) qvR/2

18. A charged particle moves with velocity $\vec{v} = a\hat{i} + d\hat{j}$ in a magnetic field $\vec{B} = A\hat{i} + D\hat{j}$. The force acting on the particle has magnitude F. Then,

(1) F = 0, if aD = dA

(2) F = 0, if aD = –dA

(3) F = 0, i f aA = – dD

(4) $F \propto (a^2 + b^2)^{1/2} \times (A^2 + D^2)^{1/2}$

19. If a particle of charge 10^{-12} coulomb moving along the $\hat{x}$ - direction with a velocity 10^5 m/s experiences a force of 10^{-10} newton in $\hat{y}$ - direction due to magnetic field, then the minimum magnetic field is

(1) 6.25×10^3 Tesla in $\hat{z}$ - direction

(2) 10^{-15} Tesla in $\hat{z}$ - direction

(3) 6.25×10^{-3} Tesla in $\hat{z}$ - direction

(4) 10^{-3} Tesla in $\hat{z}$ - direction

20. A certain region has an electric field $\vec{E} = \left(2\hat{i} - 3\hat{j}\right) N/C$ and a uniform magnetic field $B = \left(5\hat{i} + 2\hat{j} + 4k\right)T$. The force experienced by a charge 1C moving with velocity $\left(\hat{i} + 2\hat{j}\right)$ ms^{-1} is

(1) $\left(10\hat{i} - 7\hat{j} - 7\hat{k}\right)$ (2) $\left(10\hat{i} + 7\hat{j} + 7\hat{k}\right)$ (3) $\left(-10\hat{i} + 7\hat{j} + 7\hat{k}\right)$ (4) $\left(10\hat{i} + 7\hat{j} - 7\hat{k}\right)$

21. A cathode ray beam is bent in a circle of radius 2 cm by a magnetic induction 4.5×10^{-3} weber/m^2. The velocity of electron is

(1) 3.43×10^7 m/s (2) 5.37×10^7 m/s (3) 1.23×10^7 m/s (4) 1.58×10^7 m/s

22. A proton and an a-particle enter a uniform magnetic field perpendicularly with the same speed. If proton takes 25 μ second to make 5 revolutions, then the time period for the $\alpha -$particle would be

(1) 50 μsec (2) 25 μsec (3) 10 μsec (4) 5 μsec

23. A wire of length L metre carrying a current I ampere is bent in the form of a circle. Its magnitude of magnetic moment will be

(1) $IL/4\pi$ (2) $I^2L^2/4\pi$ (3) $IL^2/4\pi$ (4) $IL^2/8\pi$

24. What is cyclotron frequency of an electron with an energy of 100 e V in the magnetic field of 1×10^{-4} weber / m^2 if its velocity is perpendicular to magnetic field?

(1) 0.7 MHz (2) 2.8 MHz (3) 1.4 MHz (4) 2.1 MHz

25. A charged particle with velocity 2×10^3 m/s passes undeflected through electric and magnetic field. Magnetic field is 1.5 tesla. The electric field intensity would be

(1) 2×10^3 N/C (2) 1.5×10^3 N/C (3) 3×10^3 N/C (4) $4/3 \times 10^{-3}$ N/C

26. An electron moving with kinetic energy 6×10^{-16} joules enters a field of magnetic induction 6×10^{-3} weber/m^2 at right angle to its motion. The radius of its path is

(1) 3.42 cm (2) 4.23 cm (3) 5.17 cm (4) 7.7 cm

Topic 2: Magnetic Field Lines, Biot-Savart's Law and Ampere's Circuital Law

27. A current *I* flows along the length of an infinitely long, straight, thin walled pipe. Then

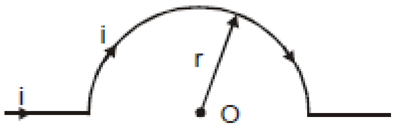
(1) the magnetic field at all points inside the pipe is the same, but not zero

(2) the magnetic field is zero only on the axis of the pipe

(3) the magnetic field is different at different points inside the pipe

(4) the magnetic field at any point inside the pipe is zero

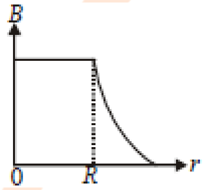
28. A portion of a conductive wire is bent in the form of a semicircle of radius r as shown below in fig. At the centre of semicircle, the magnetic induction will be

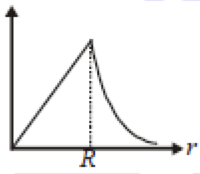


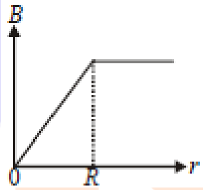
(1) zero (2) infinite (3) $\frac{\mu_0}{4\pi}.\frac{\pi i}{r}$ gauss (4) $\frac{\mu_0}{4\pi}.\frac{\pi i}{r}$ tesla

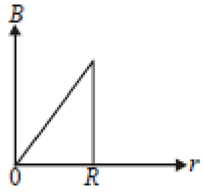
29. A straight wire of diameter 0.5 mm carrying a current of 1 A is replaced by another wire of 1 mm diameter carrying same current. The strength of magnetic field far away is
(1) twice the earlier value
(2) same as the earlier value
(3) one-half of the earlier value
(4) one-quarter of the earlier value

30. The correct plot of the magnitude of magnetic field $\vec{B}$ vs distance r from centre of the wire is, if the radius of wire is R

(1) 

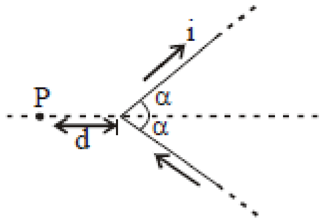
(2) 

(3) 

(4) 

31. If in a circular coil A of radius R, current I is flowing and in another coil B of radius 2R a current 2I is flowing, then the ratio of the magnetic fields B_A and B_B, produced by them will be
(1) 1 (2) 2 (3) 1/2 (4) 4

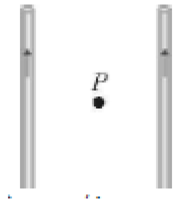
32. If the magnetic field at P can be written as K tan$\left(\frac{\alpha}{2}\right)$, the K is



(1) $\frac{\mu_0 I}{4\pi d}$ (2) $\frac{\mu_0 I}{2\pi d}$ (3) $\frac{\mu_0 I}{\pi d}$ (4) $\frac{2\mu_0 I}{\pi d}$

33. A long solenoid has 100 turns per cm and carries a current 6A. The magnetic field at its centre is 3.14 × 10^{-2} Weber/m^2. Another long solenoid has 50 turns per cm and it carries a current 2A. The value of the magnetic field at its centre is
(1) 5.66 × 10^{-3} weber/m^2 (2) 5.23 × 10^{-5} weber/m^2
(3) 7.23 × 10^{-5} weber/m^2 (4) 6.23 × 10^{-4} weber/m^2

34. Two long straight wires are set parallel to each other. Each carries a current i in the same direction and the separation between them is 2r. The intensity of the magnetic field midway between them is

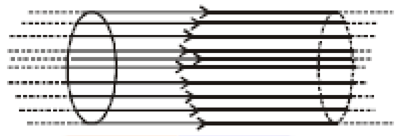


(1) $\mu_0 i/r$ (2) $4\mu_0 i/r$ (3) zero (4) $\mu_0 i/4r$

35. A current loop consists of two identical semicircular parts each of radius R, one lying in the x-y plane and the other in x-z plane. If the current in the loop is i, the resultant magnetic field due to the two semicircular parts at their common centre is

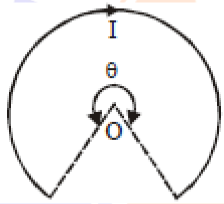
(1) $\frac{\mu_0 i}{\sqrt{2}R}$ (2) $\frac{\mu_0 i}{2\sqrt{2}R}$ (3) $\frac{\mu_0 i}{2R}$ (4) $\frac{\mu_0 i}{4R}$

36. The figure shows *n* (*n* being an even number) wires placed along the surface of a cylinder of radius *r*. Each wire carries current *i* in the same direction. The net magnetic field on the axis of the cylinder is



(1) $\mu_0 ni$ (2) $\frac{\mu_0 ni}{2\pi r}$ (3) zero (4) $\frac{\mu_0 ni}{4\pi r}$

37. A current of I ampere flows in a wire forming a circular arc of radius r metres subtending an angle θ at the centre as shown. The magnetic field at the centre O in tesla is



(1) $\frac{\mu_0 I\theta}{4\pi r}$ (2) $\frac{\mu_0 I\theta}{2\pi r}$ (3) $\frac{\mu_0 I\theta}{2r}$ (4) $\frac{\mu_0 I\theta}{4r}$

38. The magnetic field at a distance r from a long wire carrying current i is 0.4 tesla. The magnetic field at a distance 2r is

(1) 0.2 tesla (2) 0.8 tesla (3) 0.1 tesla (4) 1.6 tesla

39. The magnetic induction at a point P which is at a distance of 4 cm from a long current carrying wire is 10^{-3} T. The field of induction at a distance 12 cm from the current will be

(1) 3.33×10^{-4} T (2) 1.11×10^{-4} T (3) 3×10^{-3} T (4) 9×10^{-3} T

40. A current i ampere flows along an infinitely long straight thin walled tube, then the magnetic induction at any point inside the tube is

(1) ∞ (2) zero (3) $\frac{\mu_0}{4\pi}.\frac{2i}{r}$ tesla (4) $\frac{2i}{r}$ tesla

41. If we double the radius of a coil keeping the current through it unchanged, then the magnetic field at any point at a large distance from the centre becomes approximately

(1) double (2) three times (3) four times (4) one-fourth

42. Two long parallel wires P and Q are held perpendicular to the plane of paper with distance of 5 m between them. If P and Q carry current of 2.5 amp. and 5 amp. respectively in the same direction, then the magnetic field at a point halfway between the wires is

(1) $\mu_0/17$ (2) $\sqrt{3}\,\mu_0/2p$ (3) $\mu_0/2p$ (4) $3\mu_0/2p$

43. Two concentric circular coils of ten turns each are situated in the same plane. Their radii are 20 and 40 cm and they carry respectively 0.2 and 0.4 ampere current in opposite direction. The magnetic field in weber/m^2 at the centre is

(1) $\mu_0/80$ (2) $7\mu_0/80$ (3) $(5/4)\mu_0$ (4) zero

44. A solenoid of length 1.5 m and 4 cm diameter possesses 10 turns per cm. A current of 5A is flowing through it, the magnetic induction at axis inside the solenoid is ($\mu_0 = 4\pi \times 10^{-7}$ weber amp^{-1} m^{-1})

(1) $4\pi \times 10^{-5}$ gauss (2) $2\pi \times 10^{-5}$ gauss (3) $4\pi \times 10^{-5}$ tesla (4) $2\pi \times 10^{-5}$ tesla

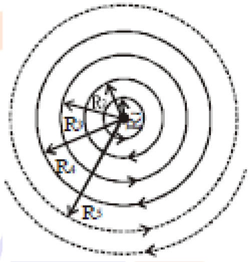
45. At what distance from a long straight wire carrying a current of 12 A will the magnetic field be equal to 3×10^{-5} *Wb/m*^{2}?

(1) 8×10^{-2} m (2) 12×10^{-2} m (3) 18×10^{-2} m (4) 24×10^{-2} m

46. A coaxial cable consists of a thin inner conductor fixed along the axis of a hollow outer conductor. The two conductors carry equal currents in opposites directions. Let B_1 and B_2 be the magnetic fields in the region between the conductors and outside the conductor, respectively Then,

(1) $B_1 \neq 0, B_2 \neq 0$ (2) $B_1 = B_2 = 0$ (3) $B_1 \neq 0, B_2 = 0$ (4) $B_1 = 0, B_2 \neq 0$

47. The figure shows a system of infinite concentric circular current loops having radii $R_1, R_2, R_3 \rightarrow R_n$. The loops carry net current *i* alternately in clockwise and anticlockwise direction. The magnitude of net magnetic field of the centre of the loops is



(1) $\frac{\mu_0 i}{2}\left[\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}+\frac{1}{R_4}+....\right]$

(2) $\frac{\mu_0 i}{2}\left[\frac{1}{R_1}-\frac{1}{R_2}+\frac{1}{R_3}-\frac{1}{R_4}+....\right]$

(3) $\frac{\mu_0 i}{4\pi}\left[\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}+\frac{1}{R_4}+....\right]$

(4) $\frac{\mu_0 i}{4\pi}\left[\frac{1}{R_1}-\frac{1}{R_2}+\frac{1}{R_3}-\frac{1}{R_4}+....\right]$

48. Axis of a solid cylinder of infinite length and radius R lies along y-axis, it carries a uniformly distributed current i along +y direction. Magnetic field at a point $\left(\frac{R}{2}y, \frac{R}{2}\right)$ is

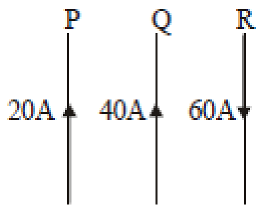
(1) $\frac{\mu_0 i}{4\pi R}(\hat{i}-\hat{k})$ (2) $\frac{\mu_0 i}{2\pi R}(\hat{j}-\hat{k})$ (3) $\frac{\mu_0 i}{4\pi R}\hat{j}$ (4) $\frac{\mu_0 i}{4\pi R}(\hat{i}+\hat{k})$

Topic 3: Force and torque on current carrying conductor and moving coil Galvanometer

49. A current of 10 A is flowing in a wire of length 1.5 m. A force of 15 N acts on it when it is placed in a uniform magnetic field of 2 T. The angle between the magnetic field and the direction of the current is

(1) 30° (2) 45° (3) 60° (4) 90°

50. P, Q and R are long straight wires in air, carrying currents as shown. The force on Q is directed



(1) to the left
(2) to the right
(3) $\perp$ to the plane of the diagram
(4) along the current in Q

51. A current carrying coil is subjected to a uniform magnetic field. The coil will orient so that its plane becomes

(1) inclined at 45° to the magnetic field
(2) inclined at any arbitrary angle to the magnetic field

(3) parallel to the magnetic field

(4) perpendicular to magnetic field

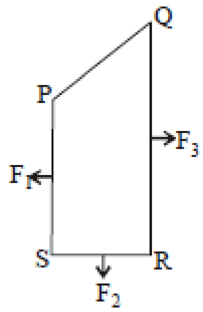
52. Two thin long parallel wires separated by a distance b are carrying a current i amp each. The magnitude of the force per unit length exerted by one wire on the other is

(1) $\frac{\mu_0 i^2}{b^2}$ (2) $\frac{\mu_0 i^2}{2\pi b}$ (3) $\frac{\mu_0 i}{2\pi b}$ (4) $\frac{\mu_0 i}{2\pi b^2}$

53. A current of 5 ampere is flowing in a wire of length 1.5 metres. A force of 7.5 N acts on it when it is placed in a uniform magnetic field of 2 tesla. The angle between the magnetic field and the direction of the current is

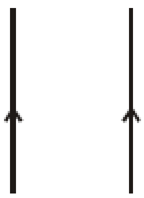
(1) 30° (2) 45° (3) 60° (4) 90°

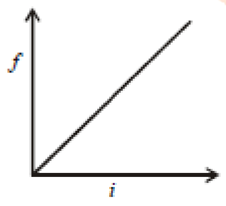
54. A closed loop PQRS carrying a current is placed in a uniform magnetic field. If the magnetic forces on segments PS, SR, and P RQ are F_1, F_2 and F_3 respectively and are in the plane of the paper and along the directions shown, the force on the segment QP is

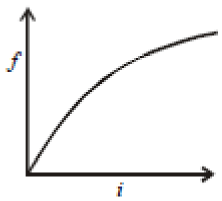


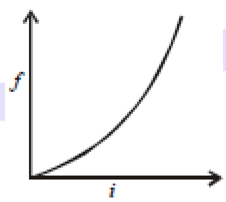
(a) $F_3 - F_1 - F_2$ (2) $\sqrt{(F_3 - F_1)^2 + F_2^2}$ (3) $\sqrt{(F_3 - F_1)^2 - F_2^2}$ (4) $F_3 - F_1 + F_2$

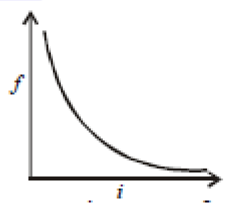
55. The figure shows two long straight current carrying wire separated by a fixed distance *d*. The magnitude of current, flowing in each wire varies with time but the magnitude of current in each wire is equal at all times. Which of the following graphs shows the correct variation of force per unit length *f* between the two wires with current *i*?



(1) 

(2) 

(3) 

(4) 

56. A moving coil galvanometer has a resistance of 900 Ω. In order to send only 10% of the main current through this galvanometer, the resistance of the required shunt is

(1) 0.9 Ω (2) 100 Ω (3) 405 Ω (4) 90 Ω

57. A conducting circular loop of radius *r* carries a constant current *i*. It is placed in a uniform magnetic field $\vec{B}_0$ such that $\vec{B}_0$ is perpendicular to the plane of the loop. The magnetic force acting on the loop is

(1) irB_0 (2) $2\pi irB_0$ (3) zero (4) πirB_0

58. A current of 3 A is flowing in a linear conductor having a length of 40 cm. The conductor is placed in a magnetic field of strength 500 gauss and makes an angle of 30° with the direction of the field. It experiences a force of magnitude

(1) 3×10^{-4} N (2) 3×10^{-2} N (3) 3×10^{2} N (4) 3×10^{4} N

59. In figure, an external torque changes the orientation of loop from one of lowest potential energy to one of highest potential energy. The work done by the external torque is closest to

(1) 0.5 J (2) 0.2 J (3) 0.3 J (4) 0.4 J

60. Through two parallel wires A and B, 10A and 2A of currents are passed respectively in opposite directions. If the wire A is infinitely long and the length of the wire B is 2m, then force on the conductor B, which is situated at 10 cm distance from A, will be

(1) 8×10^{-7} N (2) 8×10^{-5} N (3) 4×10^{-7} N (4) 4×10^{-5} N

61. A circular loop of area 0.02 m2 carrying a current of 10A, is held with its plane perpendicular to a magnetic field induction 0.2 T. The torque acting on the loop is

(1) 0.01 Nm (2) 0.001 Nm (3) zero (4) 0.8 Nm

62. A current carrying conductor placed in a magnetic field experiences maximum force when angle between current and magnetic field is

(1) $3\pi/4$ (2) $\pi/2$ (3) $\pi/4$ (4) zero

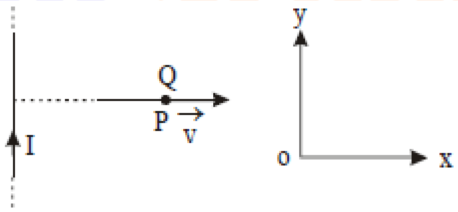
63. To increase the range of voltmeter having resistance G from V to V/n, a shunt of how much resistance should be connected in parallel to it?

(1) n^3G (2) n^2G (3) nG (4) G/n

64. In an ammeter 0.2% of main current passes through the galvanometer. If resistance of galvanometer is G, the resistance of ammeter will be :

(1) $\frac{1}{499}G$ (2) $\frac{499}{500}G$ (3) $\frac{1}{500}G$ (4) $\frac{500}{499}G$

65. A very long straight wire carries a current I. At the instant when a charge + Q at point P has velocity $\vec{v}$, as shown, the force on the charge is



(1) along oy (2) opposite to oy (3) along ox (4) opposite to ox

NEET PREVIOUS YEARS QUESTIONS

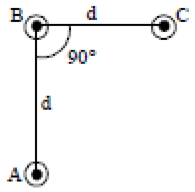
1. Current sensitivity of a moving coil galvanometer is 5 div/ mA and its voltage sensitivity (angular deflection per unit voltage applied) is 20 div/V. The resistance of the galvanometer is [2018]

(1) 40 Ω (2) 25 Ω (3) 500 Ω (4) 250 Ω

2. A metallic rod of mass per unit length 0.5 kg m^{-1} is lying horizontally on a smooth inclined plane which makes an angle of 30°with the horizontal. The rod is not allowed to slide down by flowing a current through it when a magnetic field of induction 0.25 T is acting on it in the vertical direction. The current flowing in the rod to keep it stationary is [2018]

(1) 7.14 A (2) 5.98 A (3) 11.32 A (4) 14.76 A

3. An arrangement of three parallel straight wires placed perpendicular to plane of paper carrying same current 'I along the same direction is shown in fig. Magnitude of force per unit length on the middle wire 'B' is given by [2017]

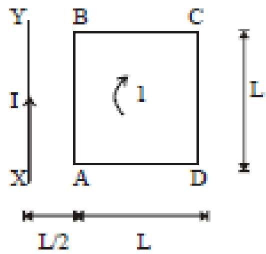


(1) $\frac{2\mu_0 i^2}{\pi d}$ (2) $\frac{\sqrt{2}\mu_0 i^2}{\pi d}$ (3) $\frac{\mu_0 i^2}{\sqrt{2}\pi d}$ (4) $\frac{\mu_0 i^2}{2\pi d}$

4. A 250-turn rectangular coil of length 2.1 cm and width 1.25 cm carries a current of 85 μA and subjected to magnetic field of strength 0.85 T. Work done for rotating the coil by 180° against the torque is[2017]

(1) 4.55 μJ (2) 2.3 μJ (3) 1.15 μJ (4) 9.1 μJ

5. A square loop ABCD carrying a current i, is placed near and coplanar with a long straight conductor XY carrying a current I, the net force on the loop will be : [2016]



(1) $\frac{2\mu_0 Ii}{3\pi}$ (2) $\frac{\mu_0 Ii}{2\pi}$ (3) $\frac{2\mu_0 IiL}{3\pi}$ (4) $\frac{\mu_0 IiL}{2\pi}$

6. A long straight wire of radius a carries a steady current I. The current is uniformly distributed over its cross-section. The ratio of the magnetic fields B and B', at radial distances a/2 and 2a respectively, from the axis of the wire is: [2016]

(1) 1/4 (2) 1/2 (3) 1 (4) 4

7. A proton and an alpha particle both enter a region of uniform magnetic field B, moving at right angles to field B. If the radius of circular orbits for both the particles is equal and the kinetic energy acquired by proton is 1 MeV the energy acquired by the alpha particle will be: [2015]

(1) 0.5 MeV (2) 1.5 MeV (3) 1 MeV (4) 4 MeV

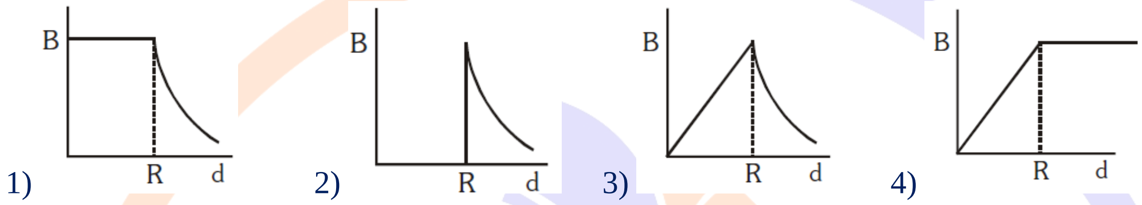
8. An electron moving in a circular orbit of radius r makes n rotations per second. The magnetic field produced at the centre has magnitude: [2015]

(1) Zero (2) $\frac{\mu_0 n^2 e}{r}$ (3) $\frac{\mu_0 ne}{2r}$ (4) $\frac{\mu_0 ne}{2\pi r}$

9. Two identical long conducting wires AOB and COD are placed at right angle to each other, with one above other such that 'O' is their common point for the two. The wires carry I_1 and I_2 currents respectively. Point ‘P’ is lying at distance ‘d’ from ‘O’ along a direction perpendicular to the plane containing the wires. The magnetic field at the point ‘P’ will be: [2014]

(1) $\frac{\mu_0}{2\pi d}\left(\frac{I_1}{I_2}\right)$ (2) $\frac{\mu_0}{2\pi d}\left(I_1+I_2\right)$ (3) $\frac{\mu_0}{2\pi d}\left(I_1^2-I_2^2\right)$ (4) $\frac{\mu_0}{2\pi d}\left(I_1^2\times I_2^2\right)^{1/2}$

10. A cylindrical conductor of radius R is carrying a constant current. The plot of the magnitude of the magnetic field, B with the distance d, from the centre of the conductor, is correctly represented by the figure: **[NEET – 2019]**



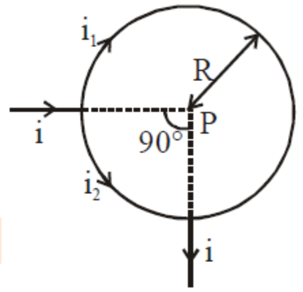
11. Ionized hydrogen atoms and a-particles with same momenta enters perpendicular to a constant magnetic field B. The ratio of their radii of their paths $r_H : r_\alpha$ will be **[NEET – 2019]**

(1) 2 :1 (2) 1 : 2 (3) 4 : 1 (4) 1 : 4

12. Two toroids 1 and 2 have total number of turns 200 and 100 respectively with average radii 40 cm and 20 cm respectively. If they carry same current i, then the ratio of the magnetic fields along the two is : **[NEET – 2019 (ODISSA)]**

(1) 1 : 1 (2) 4 : 1 (3) 2 : 1 (4) 1 : 2

13. A straight conductor carrying current i splits into two parts as shown in the figure. The radius of the circular loop is R. The total magnetic field at the centre P of the loop is : **[NEET – 2019 (ODISSA)]**



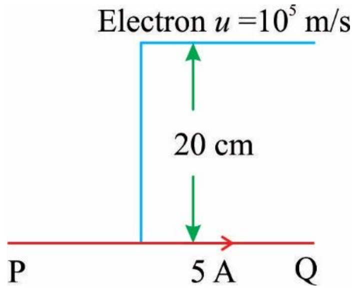
(1) Zero (2) $3\mu_0 i/32R$, outward

(3) $3\mu_0 i/32R$, inward (4) $\mu_0 i/2R$, inward

14. A long solenoid of 50 cm length having 100 turns carries a current of 2.5 A. The magnetic field at the centre of the solenoid is $\left(\mu_0 = 4\pi\times10^{-7}\,\text{T m A}^{-1}\right)$ **[NEET – 2020]**

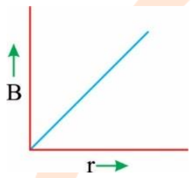
1) 3.14×10^{-5}T 2) 6.28×10^{-4}T 3) 3.14×10^{-4}T 4) 6.28×10^{-5}T

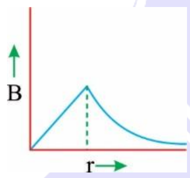
15. An infinitely long straight conductor carries a current of 5A as shown. An electron is moving with a speed of 10 m/s parallel to the conductor. The perpendicular distance between the electron and the conductor is 20 cm at an instant. Calculate the magnitude of the force experienced by the electron at that instant. **[NEET-2021]**

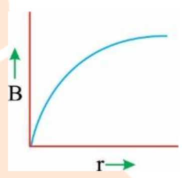


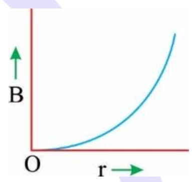
1) $8\pi \times 10^{-20}$ N 2) $4\pi \times 10^{-20}$ N 3) 8×10^{-20} N 4) 4×10^{-20} N

16. A thick current carrying cable of radius 'R' carries current 'I' uniformly distributed across its cross-section. The variation of magnetic field BI due to the cable with the distance 'r' from the axis of the cable is represented by **[NEET-2021]**

1) 

2) 

3) 

4) 

17. In the product $\vec{F} = q\left(\vec{v} \times \vec{B}\right) = q\vec{v} \times \left(B\vec{i} \times B\vec{j} + B_0\vec{k}\right)$

For q = 1 and $\vec{v} = 2\vec{i} + 4\vec{j} + 6\vec{k}$ and $\vec{F} = 4\vec{i} - 20\vec{j} + 12\vec{k}$

What will be the complete expression for $\vec{B}$? **[NEET-2021]**

1) $-6\vec{i} - 6\vec{j} - 8\vec{k}$ 2) $8\vec{i} + 8\vec{j} - 6\vec{k}$ 3) $6\vec{i} + 6\vec{j} - 8\vec{k}$ 4) $-8\vec{i} - 8\vec{j} - 6\vec{k}$

18. A uniform conducting wire of length 12a and resistance 'R' is wound up as a current carrying coil in the shape of **[NEET-2021]**

i) an equilateral triangle of side 'a' ii) a square of side 'a'

The magnetic dipole moments of the coil in each case respectively are

1) $3Ia^2$ and Ia^2 2) $3Ia^2$ and $4Ia^2$ 3) $4Ia^2$ and $3Ia^2$ 4) $\sqrt{3}\,Ia^2$ and $3\,Ia^3$

19. A long solenoid of radius 1 mm has 100 turns per mm. If 1 A current flows in the solenoid, the magnetic field strength at the centre of the solenoid is **[NEET-2022]**

1) $6.28 \times 10^{-2} T$ 2) $12.56 \times 10^{-2} T$ 3) $12.56 \times 10^{-4} T$ 4) $6.28 \times 10^{-4} T$

20. A square loop of side 1 m and resistance 1Ω is placed in a magnetic field of 0.5 T. If the plane of loop is perpendicular to the direction of magnetic field, the magnetic flux through the loop is **[NEET-2022]**

1) 2 weber 2) 0.5 weber 3) 1 weber 4) zero weber

21. Given below are two statements: **[NEET-2022]**

Statements I: Biot-Savert's law gives us the expression for the magnetic field strength of an infinitesimal current element (Idl) of a current carrying conductor only

Statement II: Biot-Savert's law is analogous to Coulomb's inverse square law of charge q, with the former being related to the field produced by a scalar source, Idl while the latter being produced by a vector source q.

In light of above statements choose the most appropriate answer from the options give below:

1) Both Statement I and Statement II are correct

2) Both Statement I and Statement II are incorrect

3) Statement I is correct but Statement II is incorrect

4) Statement I is incorrect and Statement II is correct

22. From Ampere's circuit law for a long straight wire of circuit cross-section carrying a steady current, the variation of magnitude field in the inside and outside region of the wire is: **[NEET-2022]**

(1) Uniform and remains constant for both the regions.

(2) a linearly increasing function of distance upto the boundary of the wire and then linearly decreasing for the outside region.

(3) a linearly increasing function of distance r upto the boundary of the wire and then decreasing one with 1/r dependence for the outside region.

(4) a linearly decreasing function of distance upto the boundary of the wire and then a linearly increasing one for the outside for the outside region.

NCERT LINE BY LINE QUESTIONS – ANSWERS

1)	c	2)	b	3)	a	4)	b	5)	d
6)	d	7)	b	8)	a	9)	a	10)	a
11)	b	12)	d	13)	c	14)	d	15)	b
16)	a	17)	d	18)	d	19)	d	20)	c

NCERT BASED PRACTICE QUESTIONS

1)	D	2)	D	3)	B	4)	D	5)	A
6)	C	7)	C	8)	D	9)	D	10)	D
11)	D	12)	C	13)	B	14)	A	15)	B
16)	A	17)	B	18)	C	19)	D	20)	C
21)	C	22)	A	23)	B	24)	C	25)	A
26)	B	27)	C	28)	C	29)	C	30)	C
31)	B	32)	D	33)	D	34)	E	35)	A
36)	B	37)	B	38)	C	39)	A	40)	A
41)	D								

TOPIC WISE PRACTICE QUESTIONS - ANSWERS

1) 4	**2)** 2	**3)** 2	**4)** 3	**5)** 1	**6)** 3	**7)** 4	**8)** 1	**9)** 3	**10)** 4
11) 4	**12)** 4	**13)** 2	**14)** 3	**15)** 3	**16)** 3	**17)** 4	**18)** 1	**19)** 4	**20)** 1
21) 4	**22)** 3	**23)** 3	**24)** 2	**25)** 3	**26)** 1	**27)** 4	**28)** 4	**29)** 2	**30)** 2
31) 1	**32)** 2	**33)** 1	**34)** 3	**35)** 2	**36)** 3	**37)** 1	**38)** 1	**39)** 1	**40)** 2
41) 3	**42)** 3	**43)** 4	**44)** 4	**45)** 1	**46)** 3	**47)** 2	**48)** 1	**49)** 1	**50)** 1
51) 4	**52)** 2	**53)** 1	**54)** 2	**55)** 3	**56)** 2	**57)** 3	**58)** 2	**59)** 3	**60)** 2
61) 3	**62)** 3	**63)** 3	**64)** 3	**65)** 1					

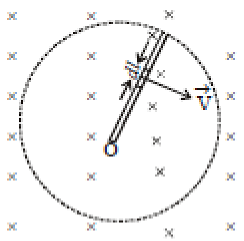
NEET PREVIOUS YEARS QUESTIONS-ANSWERS

1) 4	**2)** 3	**3)** 3	**4)** 4	**5)** 1	**6)** 3	**7)** 3	**8)** 3	**9)** 4
10) 3	**11)** 1	**12)** 1	**13)** 1	**14)** 2	**15)** 3	**16)** 2	**17)** 1	**18)** 4
19) 2	**20)** 2	**21)** 3	**22)** 3					

TOPIC WISE PRACTICE QUESTIONS - SOLUTIONS

1. **(4)** Force, $F = qVB = \frac{mv^2}{R}$ $\quad \therefore R = \frac{mv}{Bq}$

2. **(2)** The application of equation $\vec{F}_B = q\left(\vec{V} \times \vec{B}\right)$ on the element *dl* of the rod gives force on positive charge towards the outer end. Therefore electrons will move towards pivoted end.



3. **(2)** Here velocity vector have two components

(i) v $\cos\theta$, parallel to magnetic field

(ii) v $\sin\theta$, perpendicular to magnetic field. Due to component v $\cos\theta$, the particle will have a linear motion but due to v $\sin\theta$, the particle will have simultaneously a circular motion. The resultant of the two is a helical path.

4. **(3)** As $r = \frac{mv}{qB} = \frac{P}{qB}$

$\therefore$ Area $A=\pi r^2=\pi\left(\frac{P}{qB}\right)^2=\frac{\pi P^2}{qB}=\frac{2m\pi}{qB}K$

5. **(1)** Lorentz force acting on the particle

$\overline{F}=q\left[\vec{E}+\vec{v}\times\vec{B}\right]$

$=q\left[3\hat{i}+\hat{j}+2\hat{k}\begin{vmatrix}\hat{i} & \hat{j} & \hat{k}\\ 3 & 4 & 1\\ 1 & 1 & -3\end{vmatrix}\right]$

$=q\left[3\hat{i}+\hat{j}+2\hat{k}+\hat{i}(-12-1)-\hat{j}(-9-1)+\hat{k}(3-4)\right]$

$F_y=11q\hat{j}$

6. (3) Given: Length of iron rod = L

Magnetic moment of rod = M

Solution: As we know,

Magnetic moment is given by,

M=m×L (1)

According to question, when we bent the rod the pole strength of the rod remains unchanged. However, when the rod is bent in form of a semicircular arc the separation between the two poles become 2r (r is the radius of the semicircular arc).

$\therefore \pi r = L$; $r=\frac{L}{\pi}$

Therefore, the new magnetic moment will be,

M′=m×2r

$M^{|}=m\times=\frac{2L}{\pi}\times\frac{2M}{\pi}$

7. **(4)** The magnetic force acting on the charged particle is given by

$\vec{F}=q\left(\vec{v}\times\vec{B}\right)=\left(-2\times10^{-6}\right)\left[\left\{\left(2\hat{i}+3\hat{j}\right)\times10^{6}\right\}\times\left(2\hat{j}\right)\right]$

$=-4\left(2\hat{k}\right)=-8\hat{k}$

$\therefore$ Force is of 8N along – z-axis.

8. (1) a) The charged particle will get accelerated in the direction or opposite to the electric field $\vec{E}$ and will not deflected since $\vec{v} \parallel \vec{B}$

b) If $\vec{E} \parallel \vec{B}$, deflection due to magnetic field can be balanced by acceleration due to electric field.

c) $\vec{v} \parallel \vec{B} \Rightarrow \vec{F}_{mag}=0$ Since $\vec{E} \parallel \vec{B}$ the particle will get deflected.

d) $\vec{E} \parallel \vec{B}$; $\vec{v} \parallel \vec{B}$

$\Rightarrow$ the particle will get deflected.

9. (3) Force on a moving charge in a magnetic field is $q\left(\vec{v}\times\vec{B}\right)$

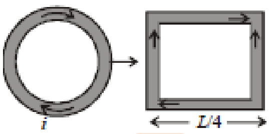
Thus if the particle is moving along the magnetic field, $\vec{F} = 0$.
Hence the particle continues to move along the incident direction, in a straight line.
When the particle is moving perpendicular to the direction of magnetic field, the force is perpendicular to both direction of velocity and the magnetic field.
Then the force tends to move the charged particle in a plane perpendicular to the direction of magnetic field, in a circle.
If the direction of velocity has both parallel and perpendicular components to the direction magnetic field, the perpendicular component tends to move it in a circle and parallel component tends to move it al

10. **(4)** Initially for circular coil $L = 2\pi r$ and $M = i \times \pi r^2$

$$= i\times\pi\left(\frac{L}{2\pi}\right)^2 = \frac{iL^2}{4\pi} \text{-------------(i)}$$

Finally for square coil side $a = \frac{L}{4}$ and

$$M^{|} = i\times\left(\frac{L}{4}\right)^2 = \frac{iL^2}{16} \text{----------------(ii)}$$



Solving equation (i) and (ii) $M^{|} = \frac{\pi M}{4}$

11. **(4)** The change in K.E. is equal to work done by net force which is zero because the magnetic force is perpendicular to velocity. K.E. remains constant.

12. **(4)** $r = \frac{mv}{qB} \Rightarrow r \propto \frac{v}{B}$

13. **(2)** $r = \frac{mv\sin\theta}{Be} = \frac{3\times10^5 \sin 30^0}{0.3\times10^8}$

$$\frac{3\times10^5\times\frac{1}{2}}{3\times10^7} = 0.5\times10^{-2} m = 0.5 cm$$

14. **(3)** The electron moves with constant velocity without deflection. Hence, force due to magnetic field is equal and opposite to force due to electric field.

$$qvB = qE \Rightarrow v = \frac{E}{B} = \frac{20}{0.5} = 40\, m/s$$

15. **(3)** $r = \frac{mv}{qB}$ or $r \propto v$

As v is doubled, the radius also becomes double.
Hence, radius = 2 × 2 = 4 cm.

16. (3) (i) When no field is present E=0,B=0, the proton experiences no force. Thus it moves with a constant velocity.
(ii) When E=0 and B=0, then there will be a probability that proton may move parallel to magnetic field. In this situation, there will be no force acting on proton.
(iii) When both fields are present
E=0,B=0, then let E, B and v may be mutually perpendicular to each other. In this case, the electric and magnetic forces acting on the proton may be equal and opposite. Thus, there will be no resultant force on the proton.

17. **(4)** Magnetic moment m = IA

Since $T = \frac{2\pi R}{v}$ Also, $I = \frac{q}{T} = \frac{qv}{2\pi R}$

$$\therefore m = \left(\frac{qv}{2\pi R}\right)\left(\pi R^2\right) = \frac{qvR}{2}$$

18. **(1)** $\vec{F} \propto \left(\vec{v} \times \vec{B}\right) = \hat{k}\left[aD - dA\right]$

19. **(4)** $F = qvB\sin\theta \Rightarrow B = \frac{F}{qv\sin\theta}$

$B_{\min} = \frac{F}{qv}$ (when $\theta = 90^0$)

$= \frac{10^{-10}}{10^{-12} \times 10^5} = 10^{-3}$ Tesla in $\hat{z}$ - direction

20. **(1)** F=qE+q(v×B)
this is loranze force

21. **(4)** $v = \frac{Bqr}{m} = \frac{4.5 \times 10^{-3} \times 1.6 \times 10^{-19} \times 2 \times 10^{-2}}{9.1 \times 10^{-31}} = 1.58 \times 10^7 \, m/s$

22. **(3)** Time taken by proton to make one revolution

$= \frac{25}{5} = 5\mu\sec$

As $T = \frac{2\pi m}{qB}$; so $\frac{T_2}{T_1} = \frac{m_2}{m_1} \times \frac{q_1}{q_2}$

or $T_2 = T_1 \frac{m_2 q_1}{m_1 q_2} = \frac{5 \times 4m_1}{m_1} \times \frac{q}{2q} = 10\mu\sec$

23. **(3)** If r is the radius of the circle,

then $L = 2\pi r$ or, $r = \frac{L}{2\pi}$

$\text{Area} = \pi r^2 = \pi L^2 / 4\pi^2 = L^2 / 4\pi$

24. **(2)** Cyclotron frequency $= f = \frac{qB}{2\pi m}$

$f = \frac{100 \times 1.6 \times 10^{-19} \times 10^{-4}}{2\pi \times 9.1 \times 10^{-31}} = 2.8\text{MHz}$

25. **(3)** $E = vB = 2 \times 10^3 \times 1.5 = 3 \times 10^3$ N/C

26. **(1)** $K.E = 6 \times 10^{-16} J$; $\frac{1}{2}MV^2 = 6 \times 10^{-16}$

$$V=\sqrt{\frac{12\times10^{-16}}{M}}\ ;\ r=\frac{MV}{qB}=\frac{M\sqrt{\frac{12\times10^{-16}}{M}}}{1.6\times10^{-19}\times6\times10^{-3}}$$

$$=\sqrt{\frac{9.18\times10^{-31}\times12\times10^{-16}}{1.6\times6\times10^{-22}}}$$

$$r=\frac{33.045\times10^{-24}}{9.6\times10^{-22}}=3.42\,\text{cm}$$

27. **(4)** There is no current inside the pipe. Therefore

$$\oint\overline{B}.\overline{d\ell}=\mu_0 I\Rightarrow I=0,\ B=0$$

28. **(4)** The straight part will not contribute magnetic field at the centre of the semicircle because every element of the straight part will be 0º or 180º with the line joining the centre and the element

Due to circular portion, the field is $\frac{1}{2}\frac{\mu_0 i}{2r}=\frac{\mu_0 i}{4r}$

Hence total field at $O=\frac{\mu_0 i}{4r}$

29. **(2)** $B=\frac{\mu_0 i}{2\pi r}$ and so it is independent of thickness.

The current is same in both the wires, hence magnetic field induced will be same.

30. **(2)** The magnetic field from the centre of wire of radius R is given by

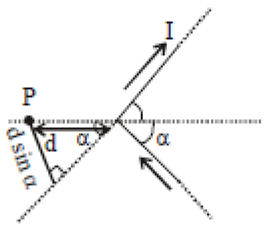
$$B=\left(\frac{\mu_0 I}{2R^2}\right)r\ (r<R)\Rightarrow B\propto r\ \text{ and }\ B=\frac{\mu_0 I}{2\pi r}\ (r>R)\Rightarrow B\propto\frac{1}{r}$$

From the above descriptions, we can say that the graph (2) is a correct representation.

31. **(1)** In coil A, $B=\frac{\mu_0}{4\pi}\frac{2\pi I}{R};\ \therefore B\propto\frac{I}{R}$

Hence, $\frac{B_1}{B_2}=\frac{I_1}{R_1}.\frac{R_2}{I_2}=\frac{2}{2}=1$

32. **(2)**



Let us compute the magnetic field due to any one segment:

$$B=\frac{\mu_0 I}{4\pi(d\sin\alpha)}\left(\cos0^0+\cos(180-\alpha)\right)$$

$$=\frac{\mu_0 I}{4\pi(d\sin\alpha)}(1-\cos\alpha)=\frac{\mu_0 I}{4\pi d}\tan\frac{\alpha}{2}$$

Resultant field will be

$$B_{net}=2B=\frac{\mu_0 I}{2\pi d}\tan\frac{\alpha}{2}\Rightarrow K=\frac{\mu_0 I}{2\pi d}$$

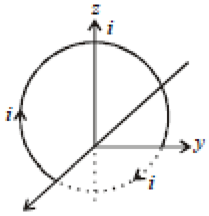
33. **(1)** $B=\mu_0 ni;\ \frac{B_1}{B_2}=\frac{n_1}{n_2}\frac{i_1}{i_2}$

$$\frac{3.14\times10^{-2}}{B_2}=\frac{100\times6}{50\times2}\Rightarrow B_2=5.66\times10^{-3}\,\text{web}/\text{m}^2$$

34. **(3)** $B=\frac{\mu_0}{2\pi}.\frac{i}{r}-\frac{\mu_0}{2\pi}.\frac{i}{r}=0$

35. **(2)** Magnetic fields due to the two parts at their common centre are respectively,

$B_y=\frac{\mu_0 i}{4R}$ and $B_z=\frac{\mu_0 i}{4R}$



Resultant field $=\sqrt{B_y^2+B_z^2}$

$$=\sqrt{\left(\frac{\mu_0 i}{4R}\right)^2+\left(\frac{\mu_0 i}{4R}\right)^2}$$

$$=\sqrt{2}.\frac{\mu_0 i}{4R}=\frac{\mu_0 i}{2\sqrt{2}R}$$

36. **(3)** Since n is an even number, we can assume the wires in pairs such that the two wires forming a pair is placed diametrically opposite to each other on the surface of cylinder. The fields produced on the axis by them are equal and opposite and can get cancelled with each other.

37. **(1)** $B=\frac{\mu_0 I}{2r}\times\frac{\theta}{2\pi}=\frac{\mu_0 I\theta}{4\pi r}$

38. **(1)** $B=\frac{\mu_0 I}{2\pi r}$ *or* $B\propto\frac{1}{r}$

When r is doubled, the magnetic field becomes half, i.e., now the magnetic field will be 0.2 T.

39. **(1)** $B=\frac{\mu_0 I}{2\pi r}\Rightarrow B\propto\frac{1}{r}$

As the distance is increased to three times, the magnetic induction reduces to one third. Hence,

$B=\frac{1}{3}\times10^{-3}\,tesla=3.33\times10^{-4}\,tesla$

40. **(2)** Magnetic induction inside a thin walled tube is zero. (According to Ampere's Law)

41. **(3)** $B_{axis}=\left(\frac{\mu_0 NI}{2x^3}\right)R^2;\ B\propto R^2$

So, when radius is doubled, magnetic field becomes four times.

42. **(3)** $B=\frac{\mu_0}{4\pi}\frac{2i_2}{(r/2)}-\frac{\mu_0}{4\pi}\frac{2i_1}{(r/2)}=\frac{\mu_0}{4\pi}\frac{4}{r}(i_2-i_1)$

$$=\frac{\mu_0}{4\pi}\frac{4}{5}(5-2.5)=\frac{\mu_0}{2\pi}$$

43. **(4)** $B=\frac{\mu_0}{4\pi}.\frac{2\pi ni_1}{r_1}-\frac{\mu_0}{4\pi}\frac{2\pi ni_2}{r_2}=\frac{\mu_0}{2}\left[\frac{ni_1}{r_1}-\frac{ni_2}{r_2}\right]$

44. **(4)** $B=\mu_0 nI=4\pi\times10^{-7}\times10\times5=2\pi\times10^{-5}T$

45. **(1)** Current (I) = 12 A and magnetic field (2) = 3×10^{-5} Wb/m^2. Consider magnetic field $\vec{B}$ at distance r.

Magnetic field, $B=\frac{\mu_0 I}{2\pi r}$

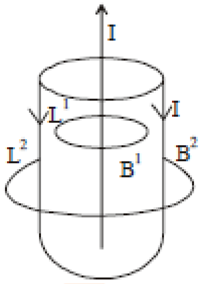
$$\Rightarrow r=\frac{\mu_0 I}{2\pi B}=\frac{\left(4\pi\times10^{-7}\right)\times12}{2\times\pi\times\left(3\times10^{-5}\right)}=8\times10^{-2}m$$

46. **(3)** Apply Ampere's circular law to the coaxial circular loops L_1 and L_2

The magnetic field is B_1 at all points on L_1 and B_2 at all points of L_2. $\sum I\neq0$ for L_1 and 0 for L_2.

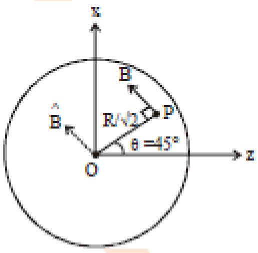
Hence, $B_1\neq0$ but $B_2=0$

$\left[As \oint \vec{B}.d\vec{l}=\mu_0\sum I\right]$



47. **(2)** Field at the centre of a circular current loop is given by $B=\frac{\mu i}{2R}$. Since the currents are alternately in opposite directions therefore the correct net field at centre is given by vector sum of field produced by each loop which are alternately in opposite directions.

48. **(1)** The magnitude of magnetic field at P



(independent on y-coordinate)

Unit vector in direction of magnetic field is

$\hat{B}=\frac{\hat{i}-\hat{k}}{\sqrt{2}}$ (shown by dotted lines)

$$\therefore\vec{B}=B\hat{B}=\frac{\mu_0 i}{4\pi R}\left(\hat{i}-\hat{k}\right)$$

49. **(1)** $F=IlB\sin\theta$ or $\sin\theta=\frac{F}{IlB}$

50. **(1)** Parallel current attracts while opposite current repel each other.

51. (4) A current carrying coil behaves as a magnetic dipole. Therefore, in a uniform magnetic field coil will get aligned such that the dipole moment of the coil is parallel to the magnetic field. And we know that dipole moment of a coil is perpendicular to its plane.

Therefore, coil will align itself such that its plane is perpendicular the direction of magnetic field.

52. **(2)** Given $i_1=i_2=i$

$$\therefore F=\frac{\mu_0 i^2 l}{2\pi b}$$

Hence force per unit length is $F=\frac{\mu_0 i^2}{2\pi b}$

53. **(1)** $F = Bil\sin\theta \Rightarrow 7.5 = 2\times5\times1.5\sin\theta \Rightarrow \theta = 30^0$

54. **(2)**

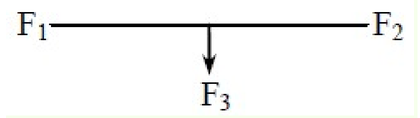
55. **(3)** The force per unit length is given by $f = \dfrac{\mu_0 i^2}{2\pi d}$

i.e., $f \propto i^2$

56. **(2)** $I_g = 0.1I$, $I_s = 0.9\,I$; $S = I_g R_g / I_s$

$= 0.1\times900 / 0.9 = 100\,\Omega$.

57. (3) Total force on the current carrying closed loop should be zero, if placed in uniform magnetic field.



$F_{horizontal}=(F_3-F_1)$

$F_{vertical}=F_2$

Resultant of $\vec{F}_1, \vec{F}_2$ and $\vec{F}_3$ is $\vec{F}$

where $F = \sqrt{(F_3 - F_1)^2 + F_2^2}$

Since total force = 0, hence force on QP is equal to F in magnitude but opposite direction.

58. (2) Force on a current carrying conductor is given as $F=ILB\sin\theta$ where θ is angle between length L and field B. i.e. 30^0

Put $B=500\times10^{-4}$Tesla and L=0.4m with I =3A we get

$F=3\times10^{-2}$N so n=3

59. (3) The potential energy of a current carrying loop kept in external magnetic field is

$U = -\vec{M}\vec{B}$

Hence work done in moving form lowest potential energy to highest potential energy=MB−(−MB)=2MB

=2×0.75×0.2J =0.3J

60. **(2)** $F = \dfrac{\mu_0}{4\pi}\dfrac{2I_1I_2}{r}\times1$

$= \dfrac{10^{-7}\times2\times10\times2}{0.1}\times2 = 8\times10^{-5}\,N$

61. **(3)** Area (1) = 0.01 m^2; Current (I) = 10A;

Angle $(\phi) = 90^0$ and magnetic field (2) =0.1T

Therefore actual angle $\theta = (90^0 - \phi) = (90^0 - 90^0) = 0^0$

And torque acting on the loop $(\tau) = IAB\sin\theta$

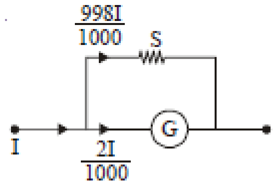
$= 10\times0.01\times0.1\times\sin0^0 = 0$

62. (3) $F=iBl\sin\theta$. This is maximum when $\sin\theta=1$ or $\theta=\pi/2$.

63. **(3)** $R = (n-1)G$; $R^{|} = Gn - G + G = nG$

64. **(3)** As 0.2% of main current passes through the galvanometer hence $\dfrac{998}{1000}I$ current through the shunt.

$\left(\dfrac{2I}{1000}\right)G = \left(\dfrac{998I}{1000}\right)S \Rightarrow S = \dfrac{G}{499}$



Total resistance of Ammeter

$$R=\frac{SG}{S+G}=\frac{\left(\frac{G}{499}\right)G}{\left(\frac{G}{499}\right)+G}=\frac{G}{500}$$

65. **(1)** The direction of B is along $\left(-\hat{k}\right)$

$\therefore$ The magnetic force

$$\vec{F}=Q\left(\vec{v}\times\vec{B}\right)=Q\left(v\hat{i}\right)\times B\left(-\hat{k}\right)=QvB\hat{j}$$

NEET PREVIOUS YEARS QUESTIONS-EXPLANATIONS

1. **(4)** Current sensitivity of moving coil galvanometer

$$I_s=\frac{NBA}{C}\ ....(i)$$

Voltage sensitivity of moving coil galvanometer,

$$V_s=\frac{NBA}{CR_G}\ ...(ii)$$

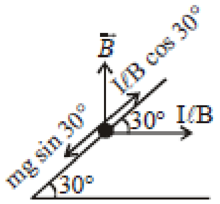
Dividing eqn. (i) by (ii)

Resistance of galvanometer

$$R_G=\frac{I_s}{V_s}=\frac{5\times1}{20\times10^{-3}}=\frac{5000}{20}=250\Omega$$

2. **(3)** From figure, for equilibrium,

mg sin 30° = I/B cos30°

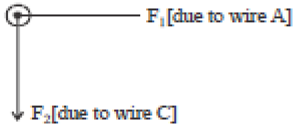


$$\Rightarrow I=\frac{mg}{\ell B}\tan 30^0$$

$$=\frac{0.5\times9.8}{0.25\times\sqrt{3}}=11.32A$$

3. **(3)** Force per unit length between two parallel current carrying conductors, $F=\frac{\mu_0 i_1 i_2}{2\pi d}$

Since same current flowing through both the wires $i_1 = i_2 = I$, so $F_1=\frac{\mu_0 i^2}{2\pi d}=F_2$



$\therefore$ Magnitude of force per unit length on the middle wire 'B'

$$F_{net} = \sqrt{F_1^2 + F_2^2} = \frac{\mu_0 i^2}{\sqrt{2}\pi d}$$

4. **(4)** Work done, $W = MB(\cos\theta_1 - \cos\theta_2)$

When it is rotated by angle 180° then

$W = MB(\cos 0° - \cos 180°) = MB(1 + 1)$

$W = 2MB = 2(NIA)B$

$= 2 \times 250 \times 85 \times 10^{-6}[1.25 \times 2.1 \times 10^{-4}] \times 85 \times 10^{-2} = 9.1$ mJ

5. **(1)** The direction of current in conductor XY and AB is same

$\therefore F_{AB} = i\ell B$ (attractive)

$$F_{AB} = \frac{\mu_0 i I}{\pi}(\leftarrow)$$

F_{BC} opposite to $F_{AD} == \dfrac{\mu_0 i I}{3\pi}(\rightarrow)$

Therefore the net force on the loop

$F_{net} = F_{AB} + F_{BC} + F_{CD} + F_{AD}$

$$\Rightarrow F_{net} = \frac{\mu_0 i I}{\pi} - \frac{\mu_0 i I}{3\pi} = \frac{2\mu_0 i I}{3\pi}$$

6. (3) Consider two amperian loops of radius a/2 and 2a as shown in the diagram.

Applying ampere's circuital law for these loops, we get

$\oint B.dL = \mu_0 I_{enclosed}$

For the smaller loop,

$$\Rightarrow B \times 2\pi\frac{a}{2} = \mu_0 \times \frac{1}{\pi a^2} \times \left(\frac{a}{2}\right)^2$$

$$= \mu_0 I \times \frac{1}{4} == \frac{\mu_0 I}{4}$$

$$\Rightarrow B_1 = \frac{\mu_0 I}{4\pi a}$$

$B' \times 2\pi(2a) = \mu_0 I$

$$\frac{B}{B'} = \frac{\mu_0 I}{4\pi a} \times \frac{4\pi a}{\mu_0 I} = 1$$

7. **(3)** As we know, $F = qvB = \dfrac{mv^2}{R}$

$$\therefore R = \frac{mv}{qB} = \frac{\sqrt{2m(kE)}}{qB}$$

Since R is same so, $KE \propto \dfrac{q^2}{m}$

Therefore KE of a particle

$$= \frac{q^2}{m} = \frac{(2)^2}{4} = 1\text{MeV}$$

8. **(3)** Radius of circular orbit = r

No. of rotations per second = n

i.e., $T = \frac{1}{n}$

Magnetic field at its centre, B_c =?

As we know, current

$$i = \frac{e}{T} = \frac{e}{(1/n)} = en = \text{equivalent current}$$

Magnetic field at the centre of circular orbit,

$$B_c = \frac{\mu_0 i}{2r} = \frac{\mu_0 ne}{2r}$$

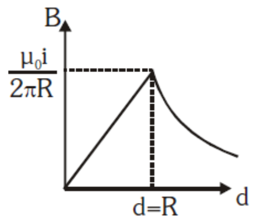
9. **(4)** Net magnetic field, $B = \sqrt{B_1^2 + B_2^2}$

$$\sqrt{\left(\frac{\mu_0 I_1}{2\pi d}\right)^2 + \left(\frac{\mu_0 I_2}{2\pi d}\right)^2} \quad \left(\because B_1 = \frac{\mu_0 I_1}{2\pi d} \text{ and } B_2 = \frac{\mu_0 I_2}{2\pi d}\right)$$

$$= \frac{\mu_0}{2\pi d}\sqrt{I_1^2 + I_2^2}$$

10.

$$B = \begin{cases} \frac{\mu_0 id}{2\pi R^2} & : \; d \le R \\ \frac{\mu_0 i}{2\pi d} & : \; d > R \end{cases}$$



11.

$$\frac{q_H}{q_\alpha} = \frac{1}{2} \qquad r = \frac{mv}{qB}$$

For same momenta, $r \propto \frac{1}{q}$

$$\frac{r_H}{r_\alpha} = \frac{q_\alpha}{q_H} = \frac{2}{1}$$

12. For a toroid magnetic field, $B=\mu_0 ni$

Where, n= number of turns per unit length $=\frac{N}{2\pi r}$

Now, $\frac{B_1}{B_2}=\frac{\mu_0 n_1 i}{\mu_0 n_2 i}$

$\frac{n_1}{n_2}=\frac{N_1}{2\pi r_1}\times\frac{2\pi r_2}{N_2}$

$\Rightarrow\frac{B_1}{B_2}=\frac{200}{2\pi\times 40\times 10^{-2}}\times\frac{2\pi\times 20\times 10^{-2}}{100}$

$\Rightarrow\frac{B_1}{B_2}=\frac{1}{1}\Rightarrow B_1:B_2=1:1$

13. Magnetic field due to $i_1=\frac{\mu_0 i_1}{2R}\frac{\theta_1}{2\pi}$

(Into the plane)

Magnetic field due to $i_2=\frac{\mu_0 i_2}{2R}\frac{\theta_2}{2\pi}$

(out of the plane)

For parallel combination $\frac{i_1}{i_2}=\frac{\rho l_2}{A}\times\frac{A}{\rho l_1}=\frac{l_1}{l_2}$

$$\Rightarrow\frac{i_1}{i_2}=\frac{\frac{1}{4}(2\pi R)}{\frac{3}{4}(2\pi R)}=\frac{1}{3}$$

$\Rightarrow i_1=\frac{i_2}{3}\Rightarrow i_2=3i_1$

$\therefore$ Net magnetic field

$$=\frac{\mu_0 i_1}{2R}\left(\frac{\theta_1}{2\pi}\right)-\frac{\mu_0 i_2}{2R}\left(\frac{\theta_2}{2\pi}\right)$$

$$=\frac{\mu_0}{2R}\left(\frac{3\pi}{2\times 2\pi}\right)-\frac{\mu_0 i_2}{2R}\left(\frac{\pi}{2\times 2\pi}\right)$$

$$=\frac{\mu_0}{2R}\left[\frac{3i_1}{4}-\frac{i_2}{4}\right]$$

$$=\frac{\mu_0}{2R}\left[\frac{3i_1}{4}-\frac{3i_1}{4}\right]=0$$

14. $B=\mu_0 ni=4\pi\times 10^{-7}\times\frac{100}{50\times 10^{-2}}\times 2.5=6.28\times 10^{-4}T$

15. $B=\frac{\mu_0 l}{2\pi r}=\frac{2\times 10^{-7}\times 5}{20\times 10^{-2}}=5\times 10^{-6}$

$F=quB=\left(1.6\times 10^{-19}\right)(10^5)5\times 10^{-6}=8\times 10^{-20}N$

16. $B_{in}=\frac{\mu_0}{2\pi}\frac{ir}{R^2}$; $B_{out}=\frac{\mu_0}{2\pi}\frac{i}{r}$

17. $\vec{F}=q\left(\vec{v}\times\vec{B}\right)$

$=q\vec{v}\times\left(B\hat{i}+B\hat{j}+B_0\hat{k}\right)$

Given $q=1,\vec{v}=\left(2\hat{i}+4\hat{j}+6\hat{k}\right)$ and $\vec{F}=\left(4\hat{i}-20\hat{j}+12\hat{k}\right)$

$$\Rightarrow\left(4\hat{i}-20\hat{j}+12\hat{k}\right)=-1\times\left(2\hat{i}+4\hat{j}+6\hat{k}\right)\times\left(B\hat{i}+B\hat{j}+B_0\hat{k}\right)$$

Thus, calculating values of RHS,

$$\begin{vmatrix}\hat{i} & \hat{j} & \hat{k}\\ 2 & 4 & 6\\ B & B & B_0\end{vmatrix}$$

$$\Rightarrow i(4B_0-6B)-j(2B_0-6B)+\hat{k}(2B-4B)$$

Comparing L.H.S and R.H.S,

$4B_0-6B-4\Rightarrow 2B_0-3B=2........(1)$

$-(2B_0-6B)=-20\Rightarrow B_0-3B=10........(2)$

$2B-4B=12\Rightarrow B=-6...............(3)$

From (2) and (3)

$B=-6$ and $B_0=-8$

Hence , $\vec{B}=-6\hat{i}-6\hat{j}-8\hat{k}$

18. Current in the loop will be V/R = I which is same for both loops.

Now magnetic moment of Triangle loop = NIA

$$M_1=\left(\frac{12a}{3a}\right)\cdot I\cdot\frac{\sqrt{3}}{4}a^2=\sqrt{3}Ia^2$$

and magnetic moment of square loop = N′IA′

$$=\left(\frac{12a}{4a}\right)\cdot I\cdot a^2 \quad M_2=3Ia^2$$

19. $B=\mu_0 ni$

$$=4\pi\times10^{-7}\times\frac{100}{10^{-3}}\times1 \quad =12.56\times10^{-2}T$$

20. $\phi=BA\cos\theta=0.5\times1^2=0.5$

21. Statement I is correct, Statement II is wrong because Idl is a vector source while in case of coulomb law, charge is a scalar source.

22. $B=\dfrac{\mu_0 i}{2\pi r}$ when $r>R$

$B=\dfrac{\mu_0 i}{2\pi R}$ when $r=R$

$B=\dfrac{\mu_0 ir}{2\pi R^2}$ when $r<R$